cancer, there is an urban factor at work. The majority of asthma sufferers in the United States live in places where the air does not meet federal standards.

On the days that she must send unusually high numbers of wheezing children home from school, my sister has begun to take note of what the weather is like, which way the wind is blowing, how the air smells, and how labored her own breathing is. Perhaps it is once again time, we both agree, to look at the environment to understand what ails us. Perhaps it is time to risk being right for the wrong reason—as did our predecessors who successfully prevented the spread of infectious disease by cleaning up pollutants in the absence of complete knowledge about the microbes they contained.

Increases in childhood asthma and the clustering of lung cancers around cities with dirty air are telling us something. Suppose we do nothing until the exact mechanisms are elucidated, until exposures are definitively ascertained, until the precise combination of air pollutants and their specific interactions with each other and with the tissues of our respiratory airways are exhaustively understood. Then are we not mimicking those who, at one time, could just as well have claimed that there was not sufficient reason—on the grounds that science had not yet identified any specific biological agent responsible for cholera—to keep human excrement out of the drinking water?

We begin the long climb up the bluff. At the top is the brokenhearted town of Creve Coeur, Pekin's smaller, meaner, drunker brother. On the other side of Creve Coeur is the road home. I celebrate by opening the sunroof.

"Aunt Sandy, when did you get this car?"

"Honey, I got it when a friend of mine in Boston was sick and needed to go to the doctor a lot. Do you remember when I told you about that?"

"She died, right?"

"Yes, she did."

"You had cancer, too, didn't you?"

In the absence of other data, it would be advisable to avoid excessive and prolonged exposure to such agents.

NINE

water

And the fish suspending themselves so curiously below
there and the beautiful curious liquid
And the water plants with their graceful flat heads, all
became part of him.
—WALT WHITMAN, "THERE WAS A CHILD WENT FORTH"

My mother grew up by the Vermilion River and my father alongside Lake Michigan. I have, therefore, no familial connection to the Illinois River, no handed-down tales to pass on. In getting to know this river I was raised beside, I've relied as much on library research as on my own observations. These sometimes tell two different stories.

In one archival photograph from the early 1900s, four men and two boys stand on the river's edge beside what looks to be an immense pile of stone butterflies. The solemn fellow in the foreground holds one of them, wings spread, in the palm of his upraised hand. The others in his outfit stand in the background, stiff and expressionless as fence posts. These men are, in fact, mussel gatherers showing off their catch. They will sell their heap of shells to one of fifteen button factories that line the shores of the lower Illinois River.

By 1948, the last one had closed. Pollution and overharvesting killed off the mussels, and plastic replaced mother-of-pearl in the production of shirt buttons. The species depicted in the photograph are as alien to me as the process of turning them into objects of human attire.

In 1948, diving ducks also began to disappear from the Illinois. Ring-necked duck, canvasback, ruddy duck, and lesser scaup: these are species I learned to identify from stuffed specimens and in distant field sites. I have been trained to recognize their patterns of coloration and differently pitched calls, but I do not recognize them as fellow inhabitants of the river system I grew up in—although it served for centuries as the flyway for their migrations.

My newlywed parents began building their house on the bluff in 1955. In this same year, the valley's population of scaups ("highly social . . . note purplish gloss on head . . . shows bold white stripe on secondaries . . . calls are short low croaks") plummeted to zero. Researchers attribute their disappearance to the synchronous demise of the river's fingernail clams. Likely poisoned by organochlorine contamination of the river's sediments, they had served as the ducks' major food source. The clams have never come back either.

Dabbling ducks, such as wigeons ("pale grey head and bluish bill") and gadwalls ("rarely congregates . . . call, very low and reedy"), feed on the seeds of aquatic plants. Their departure from the Illinois corresponds to the arrival of herbicides. As agriculture became increasingly mechanized and chemically dependent, the flow of silt and weed killers from surrounding fields created waters barren of all such vegetation. Wild celery, coontail, and sago: these species, according to old accounts, once flourished in the quiet, shallow waters of Peoria Lake. They vanished completely in the 1950s, along with the birds that ate them. I don't know how to recognize these plants.

The story of the fish begins fifty years earlier. At the turn of the twentieth century, over two thousand commercial fishers worked the Illinois and supplied their harvests to markets as far away as Boston. Special fishing trains also carried sport fishers to and from Havana, the river town just downstream of Pekin. As measured by pounds of fish caught per mile of stream, the Illinois was considered the most productive inland river in North America.

This remarkable fecundity was a gift of geology. Much of the Illinois flows through a floodplain left behind by the ancient Mississippi. This flat pan of ground allowed the river to spread out a far-flung web of interconnected backwaters—the perfect nursery, spawning grounds, and winter refuge for fish. In the summer, periodic droughts firmed up the bottom, improving conditions for vegetation. The plants, in turn, deterred the wind from stirring up sediment during periods of spring and autumn flooding, when the river poured itself into the twisting sloughs, swales, potholes, marshes, and subsidiary lakes that surrounded it.

Then came the Chicago Sanitary & Ship Canal. This part of the story is a kernel of central Illinois lore. The S&S Canal opened January 17, 1900, and effectively connected Lake Michigan to the Illinois River, creating a continuous navigational route down to New Orleans. This is the meaning of the second *S* ("ship"). The first *S* ("sanitary") refers to the flushing of Chicago's wastewater into this canal and, from there, through the Des Plaines River and into the Illinois. Consequently, the level of the Illinois rose considerably. Backwaters flooded and stayed flooded. Bottomland groves of pin oak and pecan trees died. A wave of industrial pollution moved slowly and inexorably south (reaching Pekin around 1915), and downstream residents protested vociferously. Finally in 1939, the U.S. Supreme Court was moved to reduce by one-half the diversion of water into the Illinois. In the meantime, locks and dams began shaping the river into a series of stepped navigational channels. By World War II, the river resembled its present configuration. Straightened, leveed, drained, and dammed, the Illinois River became a sewage canal for industry and a barge canal for shipping—S&S. A report published the year I turned seven features a photograph of Illinois River fish with open sores and fins eroded down to stumps.

The federal Clean Water Act of 1972 brought a modicum of improvement to the Illinois River. As annual amounts of industrial waste released into the river declined, water quality improved. The longterm ecological effects, however, are less clear. Like a cloth already frayed, the river shows signs of continued damage even at lower levels of stress. Recovery has been uneven, at best. Mussels have returned to some parts of the river, and fin erosion is a less common problem in fish. On the other hand, the level of pesticide contamination remains high, and aquatic plants have been unable to reestablish themselves.

In the Upper Illinois, fish advisories continue to caution sport anglers to severely limit—or eliminate—their consumption of fish known to contain high levels of cancer-causing chemicals. These warnings, most strict for children and women of reproductive age, are especially emphatic about the danger of eating large fish, in which the amplifying effects of biomagnification have had the longest time to operate. The bigger the fish, the more concentrated the poison.

This, then, is the river I know. Isolated from its floodplain by levees, factories, and farms, the Illinois River flows alone. Barge convoys, big as football fields, suck the river into their wakes and then send it crashing against the banks. The accompanying tugs churn the river like egg beaters, constantly resuspending toxic materials. These include vintage chemicals—PCBs, DDT, dieldrin, chlordane, heptachlor—as well as more contemporary pollutants contributed by industrial discharges, chemical spills, and farm runoff. The resulting waves slosh silt and poison into whatever fish-spawning backwaters still exist.

More than 350 different spills of hazardous substances into the waterway were reported between 1974 and 1989 alone. The continued absence of bottom-dwelling animals makes the aquatic biologist Doug Blodgett of the Illinois Natural History Survey in Havana suspect that such spills remain frequent. Killing as it goes, each spill creates a toxic pulse that moves through a given section of stream within hours. Once-a-month monitoring does little to detect most of these transient accidents. Such spills are, of course, in addition to routine industrial discharges.

⁂

The fastest way to get to the Illinois River from my parents' house is to follow Derby Street into Normandale. This was the route I used in high school—unbeknownst to my parents, who considered the riverfront dangerous.

Derby Street itself is an avenue of nostalgia and munitions. Storefronts with names like Karen's Kountry Kottage and Grandma's Feather Bed alternate down the block with various gun and ammo shops. One is notable both for the missiles on display in the parking lot and for the half of a Jeep (with GI mannequin positioned in the driver's seat) mounted trophy-style on the side of the building. Actually getting to the river from here is tricky. It requires a stroll through the subdivision, a climb over chain-link fencing, and a firm decision to ignore No Trespassing signs. Then, abruptly, there is the water—brown, familiar, blank.

Silence is comfortable here. The river embraces silence. The Illinois River seemed to me, as a teenager, not so much dangerous, or even endangered, as reassuring.

Standing here now, aware of all that is not here, I start to wonder whether I have become a natural historian of ghosts. Since 1908, twenty species of fish have disappeared from this river. One in every three native amphibian species have been completely, or almost completely, extirpated from the state. In their extinction, they join one in every five crayfish and more than half the species of mussels. The river reminds me of a poem by Robert Frost that asks, "What to make of a diminished thing?" and provides no answer.

⁂

Water is regulated much the same way food is. Just as food has tolerances, drinking water has maximum contaminant levels. These represent the highest limits allowable by law of particular toxic substances in public water supplies.

In at least two respects, maximum contaminant levels for drinking water are a more stringent measure than food tolerances. Recall from Chapter Seven that only a very tiny slice of all the food shipped, sold, and consumed in the United States is actually tested for contaminants. In contrast, *all* public drinking water is monitored on a regular, ongoing basis. Furthermore, food tolerances govern only pesticides, whereas maximum contaminant levels in drinking water regulate pollutants from both industry and agriculture. For example, there is one maximum contaminant level for the herbicide atrazine (3 parts per billion) and another for the dry-cleaning fluid perchloroethylene (5 parts per billion). The maximum contaminant level for PCBs is 0.5 parts per billion, while those for the banned pesticide chlordane and the PVC feedstock vinyl chloride each stand at 2 parts per billion. The legal limit for the phthalate plasticizer DEHP is 6 parts per billion.

As with food tolerances, these numbers have been arrived at through a compromise between public safety and economics. Maximum contaminant levels are not a health-based standard. Instead, they take into consideration cost and the ability of available technology to reduce contaminants to particular levels. These then become the legal benchmark. For many chemicals, two numbers exist: the enforceable maximum and the health-based maximum-contaminant-level *goal*, officially defined as "a non-enforceable concentration of a drinking water contaminant that is protective of adverse human health effects and allows an adequate margin of safety." The enforceable values for the carcinogens benzene, vinyl chloride, and trichloroethylene, for instance, have been set at 5, 2, and 5 parts per billion, respectively. Their maximum-contaminant-level goals, however, are all zero.

Like an accountant who proficiently measures and records individual values but fails to sum the results, this system of regulating contaminants in water suffers from the same constricted one-chemical-at-a-time vision as the parallel system of regulating pesticide residues in food. It ignores exposures to combinations of chemicals that may act in concert. Radon gas and arsenic, for example, occur naturally in some aquifers tapped for public drinking water. Both are considered human carcinogens. Maximum contaminant levels have been established for each, and each is supposed to be regulated below those levels. However, if water containing these two elements is also laced with traces of herbicides, dry-cleaning fluids, and industrial solvents—even at concentrations well below their respective legal limits—the resulting mixture may well pose hazards not recognized by a laundry list of individual exposure limits. Exposure to one compound may decrease the body's ability to detoxify another, for example.

In other ways, maximum contaminant levels are a more lenient standard than tolerances. For one thing, there are far fewer of them. As of 1996, enforceable limits had been established for a mere eighty-four contaminants. Indeed, some pesticides strictly regulated in food are not regulated at all in drinking water. For example, no maximum contaminant level exists for the herbicide cyanazine, even though it has been registered since 1971 and even though concerns about its carcinogenic properties recently prompted a phaseout of its use. Cyanazine has been detected in wells in fourteen different states and in rivers and streams throughout the Corn Belt. In some Illinois drinking-water supplies, cyanazine detections continue to exceed health-based advisory limits. But because no enforceable standard exists, these detections do not constitute violations of the law. In 1991, the National Research Council expressed official concern about water contaminants without legal limits: "The absence of evidence of their risk is solely the result of the failure to conduct research; it should not be misconstrued that [unregulated pollutants] are without risk."

To the question, then, of whether drinking water is regulated on the basis of sound scientific knowledge, the answer is no. Perhaps most revealing of all is the fact that regulation for some contaminants is based on the annual average of four quarterly measurements. In other words, drinking-water standards are violated only when the yearly mean concentration of said contaminant exceeds its maximum contaminant limit. A one-time transgression does not automatically create a violation. This distinction is important in the Midwest, where herbicide concentrations in drinking water drawn from rivers and streams often reach hair-raising levels during the spring quarter, the months of planting and rain.

In 1995, in the first study of its kind, researchers sampled water from faucets in kitchens, offices, and bathrooms every three days from mid-May through the end of June in communities throughout the Corn Belt. Herbicides turned up in the tap water in all but one of twenty-nine towns and cities. Atrazine, the suspected breast carcinogen, exceeded its maximum contaminant level in five cities, including Danville, Illinois, where its concentration in water reached six times the legal limit. Danville is southeast of Pekin, near the Indiana border. My Uncle Jack grew up there.

Food shipments, of course, are seized on the basis of single vio-

lations. The issue of whether pesticide residues in milk or asparagus
or animal crackers eventually settle into an acceptable average over
time is not considered relevant. Nor should it be. Biologically speak-
ing, we live only in the present. Our bodies do not respond to conta-
minants on the basis of averages; they must cope the best they can
with the load of contaminants already received as well as with those
streaming in at any given moment. If, during the period of April
through June, a woman living in rural Illinois drinks enough weed
killer to overwhelm her body's ability to detoxify it, and if, as some
animal evidence suggests, these chemicals are capable of initiating
and/or promoting genetic lesions in her breast tissue, then the dam-
age has been done, regardless of what happens during the months of
August, October, or January.

This issue is even more critical for infants and children. Many
researchers believe that exposure to even minute amounts of carcino-
gens at certain points in early development can magnify later cancer
risks greatly. What are the implications for the unborn child who
happens to reach one of these key points at the same time a bevy of
farm chemicals in the local water supply is reaching its peak? What
are the implications for the adolescent girl whose breast buds start to
form during this particular quarter of the calendar year?

However imperfect, the current system of monitoring and regulating
drinking water does provide crucial information unavailable before
this decade. A younger sibling of the Clean Water Act, the federal
Safe Drinking Water Act became law in 1974 and brought all com-
munity water systems under federal and state regulation. It required
the EPA to set legal limits for contaminants and placed the states in
charge of enforcing these limits. Maximum contaminant levels for
most organic chemicals were established only with the amendments
of 1986, and maximum contaminant levels for many common insec-
ticides and herbicides were promulgated as recently as 1991. To its
credit, Illinois was the first state to comply with these new regulations
and began routine monitoring of farm chemicals in drinking water in
1992. Illinoisans thus have a more complete chronicle of water con-
tamination than do residents in many other states.

While it is shocking to contemplate how many decades have

passed between the widespread introduction of synthetic organic chemicals into the environment and the decision to quantify their presence in the water we drink, the data now available to us are valuable in the most intimate way: compliance monitoring data of finished drinking water describe the actual contaminants to which we are exposed whenever we turn on the faucet.

Happily, a recent right-to-know clause added to the Safe Drinking Water Act makes this information more accessible to the public. Under 1996 amendments, water utilities must tell customers, in their water bill and at least once a year, what pollutants have been detected in their drinking water and whether water quality standards have been violated. The law also mandates the creation of a national database of contaminants found in drinking water. Previously, national records did not tally contaminants unless they constituted actual violations.

Exposure to waterborne carcinogens is more commonplace than many people realize. In the same way that intake of airborne pollution involves the food we eat as well as the air we breathe, intake of contaminants carried by tap water involves breathing and skin absorption as well as drinking. These alternative routes are especially important for the class of synthetic contaminants called volatile organics—carbon-based compounds that vaporize more readily than water. The solvent tetrachloroethylene is a common one. Most are suspected carcinogens.

We have already seen in Chapter Eight how volatile organic compounds combine with nitrogen oxides to create poisonous ground-level ozone, a major air contaminant. As a contaminant of tap water, they present additional dangers. Volatile organics are easily absorbed across human skin and enter our breathing space when they evaporate. The higher the water temperature, the greater the rate of evaporation. Humidifiers, dishwashers, and washing machines all transform volatile waterborne contaminants into airborne ones, as does cooking. These sources of exposure are thought to be particularly worrisome for infants and women home all day engaged in housework.

The simple, relaxing act of taking a bath turns out to be a significant route of exposure to volatile organics. In a 1996 study, the exhaled breath of people who had recently showered contained elevated levels of volatile organic compounds. In fact, a ten-minute shower or a thirty-minute bath contributed a greater internal dose of these volatile compounds than drinking half a gallon of tap water. Showering in an enclosed stall appears to contribute the greatest dose, probably because of the inhalation of steam.

The particular route of exposure profoundly affects the biological course of the contaminant within the body. The water that we drink and use in cooking passes through the liver first and is metabolized before entering the bloodstream. A dose received from bathing is dispersed to many different organs before it reaches the liver. The relative hazards of each pathway depend on the biological activity of the contaminant and its metabolic breakdown product, as well as on the relative sensitivity of the various tissues exposed along the way.

The bathing studies raise additional questions about drinking-water standards. Once again, we see how narrow the purview of these regulations is. The environmental scientists Clifford Weisel and Wan-Kuen Jo, the authors of the 1996 study, pointedly explained:

> Traditional approaches for evaluating exposure to and adverse health effects from contaminants in tap water have assumed that ingestion is the major route of exposure. . . . Furthermore, the ingestion of two liters of water has been used to estimate the health risk associated with waterborne chemical contaminants and the establishment of drinking water standards without quantifying the doses received from other routes. This practice can lead to an underestimation of the potential health risk.

The work of Weisel, Jo, and others also helps explain an unusual finding in Rockford, Illinois. In 1984, an environmental investigation into the dumping practices of an electroplating company led to the incidental discovery that more than 150 private wells and one municipal well were polluted with volatile organochlorine solvents. Levels varied but in some cases exceeded five hundred parts per billion. Southeast Rockford was thus catapulted onto the Superfund National Priorities List.

In a study initiated five years later, researchers found elevated

levels of these same chemicals in the air space of homes receiving water from the affected wells—and in the blood of their human occupants. Curiously, blood levels correlated more closely with household air levels than with actual water levels. Air levels, in turn, were roughly correlated with length of "shower run times." These results were based on a small study population and therefore have low statistical power. However, they support the notion that inhalation contributes more significantly to overall body burden of volatile organic compounds than drinking—even when water contamination is dramatic. Bottled water, by this accounting, is not the answer.

* * *

Not long ago, I came across a survey form used in 1918 by Illinois inspectors of wells and cisterns. Among its many questions, one required measuring the distance between the water source under inspection and all possible sources of pollution. Singled out for specific mention were feedlots, privies, stables, cesspools, and "dumping grounds for slops." The survey also inquired whether small animals could fall in at the top and, most important, whether any cases of typhoid fever had ever been attributed to use of this water.

The survey's approach to protecting drinking water seemed to me to show remarkable foresight. The thrust of its questions reflect an understanding about the relationship between the safety of drinking water and the kinds of activities that go on near the source of that water. "What care is taken in collecting and storing water?" "State general condition of health of those using water." "Is the drainage from all these places toward or away from the Well, Spring, or Cistern?" "If there is any other possible source of pollution, state it." Apparently, somewhere in the transition from the age of waterborne contagion to the age of chemical carcinogens, this type of consciousness was lost. Awareness was replaced by unthinkingness.

A lengthy report on groundwater quality in my hometown was released in 1993. It contains a detailed description of contamination in two of Pekin's seven drinking-water wells. Located near the river, both wellheads are close to various industrial sites, many underground storage tanks, and the local sewage treatment plant. The chemicals detected in the water—tetrachloroethylene and 1,1,1-trichloroethane—could have migrated in from any number of possible sources. Both are suspected carcinogens. The report's assessment team expresses specific concern about a site on Second Street once occupied by Valley Chemical and Solvents Corporation. Upon closing its doors in 1989, Valley Chemical left behind a shameful trail of soil and water contamination. Its property was, you might say, a dumping ground for slops.

The city of Pekin responded swiftly to this report. Committees were established and city ordinances proposed. A course on groundwater protection was even added to the public grade school curriculum. Before all this flurry of activity, however, the initial reaction was one of astonishment. "Nothing has been done through the years to protect that aquifer," the mayor of Pekin admitted in the newspaper. "Nobody really ever thought about it. We always had good water and nobody ever thought that would change."

* * *

"Have any cases of cancer ever been attributed to use of this water?" is a more difficult query than one asking about typhoid fever cases. No one is more knowledgeable about the nature of this difficulty than Kenneth Cantor, an environmental epidemiologist and senior scientist at the National Cancer Institute. Cantor has studied the relationship between water pollution and human cancer for much of his career.

In the introduction to a recent review, Cantor and his colleagues noted that discoveries of synthetic chemical contamination in drinking water are becoming increasingly common, while epidemiological investigations into their health effects remain few. Two reasons behind the collective reluctance to launch such studies should sound familiar: there is the limitation of focusing on small populations exposed to contaminant levels high enough to yield statistical significance, and there is the problem of ascertaining past exposures. Widespread chemical contamination of drinking water may be an unintentional, ongoing human experiment, but it is one that runs without the benefit of controls or experimental design.

Most of the studies that do exist are ecological in design, that is, they simply describe patterns of association between health problems and environmental problems. We have examined a few of these already. Recall from Chapter Four that bladder cancer mortality was elevated among men (but not women) living near Pennsylvania's infamous Drake Superfund site, an old chemical dumping ground full of known bladder carcinogens. On Cape Cod, high rates of bladder cancer and leukemia were associated with living in homes serviced by vinyl-lined water pipes that were leaching tetrachloroethylene. Recall also the nationwide study in which cancer mortality was found to be elevated in U.S. counties where drinking water was contaminated by leaking hazardous waste sites.

Similar studies have been conducted in other settings, both urban and rural. In New Jersey, researchers found associations between volatile organic compounds in municipal water and leukemia among women (but not men). In Iowa, lymphoma rates were elevated in counties where drinking water was drawn from dieldrin-contaminated rivers. In Massachusetts, childhood leukemias in the industrial town of Woburn were linked to a pair of water wells contaminated with chlorinated solvents. In North Carolina, a cancer cluster in the rural community of Bynum was linked to consumption of river water contaminated upstream with both agricultural and industrial chemicals. This study is particularly compelling because the sudden increase in cancer deaths that emerged in the 1980s corresponds closely with the time of peak exposure to known carcinogens in the river (1947 to 1976) once the normal latency period for cancer is factored in. Likewise in Woburn, the surge in childhood leukemias coincides with a period of known water contamination and abates a few years after the imputed wells closed down. (Public outcry about the plight of Woburn's children played a direct role in the creation of the Massachusetts Cancer Registry.)

Corroborating evidence also comes from abroad. In a study from China, liver cancer was strongly associated with drinking water from ditches containing agricultural chemicals. In Germany, excess cases of childhood leukemia in villages near uranium mines have been tentatively linked to radium-contaminated drinking water. And in Finland, high rates of non-Hodgkin's lymphoma were discovered in a rural community where water was contaminated by chlorophenols, probably from local sawmills. Used for treating lumber, chlorophenols are related chemically to the phenoxy herbicides, which are also linked to non-Hodgkin's lymphoma.

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In a practice that began early in the twentieth century, the city of Chicago began in 1908 to pour chlorine into wastewater before sending it downstream. In the same year, the waterworks of Boonton, New Jersey, became the first to add chlorine to water intended for drinking. Chlorination proved a cheap, effective means of halting waterborne epidemics during World War I. By 1940, about 30 percent of community drinking water in the United States was chlorinated, and at present, about seven of every ten Americans drink chlorinated water.

Over the past two decades, nearly two dozen studies have emerged that link chlorination of drinking water to bladder and rectal cancers and, in some cases, to cancers of the kidney, stomach, brain, and pancreas. These investigations include case-control and cohort studies in addition to ecologic studies. The collective evidence on water chlorination, affirms Kenneth Cantor, "supports concern over an elevated carcinogenic risk."

Upon hearing this news, many otherwise even-tempered individuals may feel tempted to throw up their arms in frustrated despair, as though they had just been asked to choose between death by cancer and death by cholera. Happily, this is not our predicament. Far less gloomy options are available. They will not be realized, however, unless we recognize the hazards created by the approach presently used to combat disease pathogens in our drinking water and, with this knowledge, insist on safer practices.

Chlorine gas is a noxious posion. However, the problem with chlorinated drinking water does not lie with chlorine itself. Rather, in a manner reminiscent of the way that air pollutants combine in the atmosphere to create new chemical species, the problem begins when elemental chlorine spontaneously reacts with organic contaminants already present in water. Their organochlorine offspring are known

as disinfection by-products. Hundreds exist, and several are classified as probable human carcinogens. Trihalomethanes, a small subgroup of volatile disinfection by-products, are currently receiving the most scientific and regulatory attention. Chloroform is the most common one. As with any waterborne volatile compound, our route of exposure to trihalomethanes is threefold: ingestion, inhalation, and absorption. Indeed, trihalomethanes appear as one of the major chemical culprits in the bathing studies already discussed.

Volatile organic compounds in drinking water, then, can have variant life histories. Some may be escapees from landfills, waste dumps, farm fields, or industrial parks. These compounds arrive in our water supply ready-made, their chemical conformations intact. Others may be formed on-site at the waterworks. In this way, the chloroform present in finished tap water has at least two possible pedigrees: it could have leaked into the water supply as a contaminant, or it could have been created during the process of chlorination. All volatile organic compounds classified as trihalomethanes are regulated as a group, regardless of the precise genealogy or the individual components of the mixture. Their maximum-contaminant-level is 100 parts per billion. Their maximum-contaminant-level goal is zero. In the EPA's chart of drinking-water standards, along the row labeled "Total Trihalomethanes" and under the column titled "Potential Health Effects" is a single word: *cancer.*

Many studies all telescope into this one word. The early investigations were ecological in design and compared cancer rates in communities with and without chlorinated water. Conducted in Ohio, Louisiana, Wisconsin, Iowa, Norway, and Finland, these studies consistently found associations between water chlorination and cancers of the bladder and rectum. In a second wave of case-control and cohort studies, researchers then pursued the link between cancer and chlorination more intensely. These researchers interviewed individuals about the details of their tap-water habits, controlled for lifestyle confounders, used historical water records to estimate past exposures, and even gathered information about the sources of drinking water at previous residences. Carried out in Wisconsin, Illinois, Louisiana, Massachusetts, Maryland, North Carolina, Colorado, and Norway, these studies suggested an association between water chlorination and cancer, especially in regard to bladder and rectal cancers, and especially when drinking water is drawn from above-ground sources, such as rivers.

One of the most ambitious of these investigations was led by Kenneth Cantor himself. His research team personally interviewed nine thousand people living in ten different areas of the United States. Individual histories were then combined with water utility data to create a lifetime profile of drinking-water use for each respondent. In the final analysis,

> bladder cancer risk increased with the amount of tap water consumed, and this increase was strongly influenced by the duration of living at residences served by chlorinated surface water. . . . There was no increase of risk with tap water consumption among persons who had lived at places served by nonchlorinated ground water for most of their lives.

Giving people cancer in order to ensure them a water supply safe from disease-causing microbes is not necessary. Part of the solution lies in making wider use of alternative disinfection strategies. These include granular activated charcoal (which binds with contaminants and removes them) and ozonation (which bubbles ozone gas through raw water to kill microorganisms). Both techniques have been used successfully in many U.S. and European communities.

Part of the solution lies in directing a spirit of urgency, inventiveness, and ingenuity toward the development of other approaches. No doubt many technologies await discovery, requiring only the devotion of resources and a collaboration of creative minds to bring them into existence.

Finally, part of the answer lies in keeping carbon-based contaminants out of drinking water in the first place. This last dictum is doubly important. Less organic content means fewer trihalomethanes. Less organic content also knocks down the number of microorganisms, thereby reducing the amount of chlorine needed for disinfection. Tellingly, water from lakes, rivers, and reservoirs generates more trihalomethanes upon chlorination than does water drawn from aquifers. This is because, in general, surface water carries more organic matter than groundwater. Some of the progenitors of trihalomethanes are natural and unavoidable: decaying leaves, fallen feathers, and grains of pollen, for example. These all contribute to the total carbon load in a body of water. But many others are neither natural nor unavoidable: sewage, chemical spills, industrial discharge, soot and other fallout from air pollution, agricultural runoff, and motor oil, for instance. Drastically reducing these inputs would go a long way toward solving the problem of disinfection by-products—as well as other grosser forms of water contamination.

This part of the solution requires that water utilities and the water-consuming public become vigilant about the protection of watersheds and aquifers. Guarding water supplies means more than keeping swimmers out of reservoirs and erecting fences around wellheads. In some regions, this kind of protection will require new thinking about agriculture, which needs to substitute the techniques of organic farming for practices that pour soil and pesticides into river systems. In regions where cattle feedlots and hog farms periodically send lava flows of manure into watersheds, it will require new thinking about animal husbandry. In other areas, it will require new thinking about industry. Manufacturers must find safer alternatives to organic solvents and other synthetic carbon-based chemicals that are released into water directly, fall off barges in transit, waft into the air only to rain down elsewhere, or eventually worm their way into water via landfills and dump sites. Finally, in all regions, protection of water supplies will require new thinking on the part of individual citizens, who are asked to assume the frightening cancer risks that others have decided, on their behalf, are acceptable.

Back at the waterworks, additional improvements are possible. For example, making chlorination the last step of water treatment, rather than the initial one, lowers the amount of trihalomethanes generated, especially if the water is carefully filtered through granulated charcoal first. Artificial membranes can remove a slew of contaminants, including pesticides and solvents. Water can also be aerated to allow volatile organic compounds, including trihalomethanes, to vaporize. Because they transfer contaminants from drinking water to other environmental media, I consider these kinds of solutions less beneficial than a comprehensive strategy of primary prevention. Aeration sends waterborne organic compounds into the atmosphere where we can inhale them, and filters and membranes fill with toxic chemicals, which must go somewhere. Even while providing some immediate respite from exposure through tap water, these technological shell games keep carcinogens in circulation.

In 1910, a New Jersey court examiner declared that chlorination left "no deleterious substances in the water." He was wrong. Nevertheless, it is clear that the disinfection of drinking water with chlorine has prevented widespread contagion and death, even as it has also contributed to the burden of human cancers. I do not advocate a ban on the chlorination of drinking water. But neither do I believe we should blithely continue old disinfection practices as though our bodies and our water supplies still existed in the world of ninety years ago. I say this as an ecologist with a personal relationship to bladder cancer. In 1910, chloroform was not considered a deleterious substance. When its toxicity was later recognized, its use as a surgical anesthetic was phased out. We need not be forced to drink it now as the price for contagion-free water.

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At dead center, in the channel used by barges, the Illinois River is about as deep as the deep end of a swimming pool. If you dove to the bottom here, you would first pass through a flocculent layer of silt many feet deep. Underneath this fluffy mass is the clay trough of the riverbed. If you could somehow continue the descent, drilling down through this foundation, you would eventually find yourself once again in water—the water under the water—which is held between the glittering sand grains of the Sankoty Aquifer.

This underground basin not only lies beneath the river but stretches out for miles along its east flank and extends south toward Havana. It occupies what was once the valleys and snaky tributaries of the ancient Mississippi River—before they were bulldozed by glaciers. The Sankoty Aquifer is the source of Pekin's drinking water.

Technically speaking, an aquifer refers not to the groundwater it holds but to the collection of grit, gravel, clay, and rock the water flows through. The Sankoty ranges from 50 to 150 feet thick and

consists mostly of quartz sand grains ranging in size from dust to marbles. They are said to be distinctly pink. Sankoty sand grains are also, I'm told, neatly sorted and stratified by size, indicating they were once carried along and then deposited by the flow of a melting glacier. The resulting outwash is referred to as a valley train. Aquifers can include any porous and permeable material, such as unsorted scrap gouged up and laid back down by the glacial ice itself—this would be called till—or layers of wind-blown silt, which geologists have named loess.

Regardless of materials, aquifers come in a few basic varieties. Bedrock aquifers are covered by a lid of impermeable materials. Artesian aquifers, often lying on a slant, are under hydrostatic pressure. Water-table aquifers are like uncovered pots with rain and melting snow periodically dribbling in through the overlying soil. Their surface, the water table proper, rises and falls with seasonal fluctuations in precipitation. The Sankoty is a very large water-table aquifer.

The chemical contamination of the Sankoty Aquifer is an ongoing story with no identifiable beginning, no defining catastrophic event, and nothing that could reasonably be called a resolution. Even before the 1993 assessment roused Pekin's residents into action, there were signs of trouble. As part of a 1989 survey, the Illinois Environmental Protection Agency discovered "a substantial level" of 1,1,1-trichloroethane in one of Pekin's drinking-water wells and low levels of benzene and tetrachloroethylene in another. A year later, the Illinois EPA issued two groundwater contamination advisories after accidents at loading docks sent into the public water wells of Creve Coeur a variety of gasoline additives and crude oil derivatives. Then, in the spring of 1991, high river levels contributed to the capture of chemical contaminants in a community drinking well in north Pekin.

This last discovery was particularly unsettling. The interchange between groundwater and surface water is normally a one-way affair with aquifers, recharged by rain, emptying themselves into the rivers and streams that lie across them. Barring a flood, flow of river water into groundwater is not supposed to happen. Abrupt increases in river volume or heavy pumping from wells can, however, alter the direction of these unseen currents and possibly divert surface water into the underground world of aquifers. Water levels inside certain Sankoty wells, for example, appear to fluctuate in tandem with lock-and-dam operations on the Illinois River, implying a more reciprocal communion between these two bodies of water than was once presumed.

In light of this and other ominous realizations, the results of the groundwater assessment actually appear quite mild. Industrial chemicals turned up in a few discrete locations, but the field team found no signs of aquiferwide contamination. Indeed, the authors of the study expressed surprise at not stumbling on an even bigger problem, especially after they reviewed the history of industrial practices within the local area: "Any contaminant that could have been produced, almost certainly was produced. And yet, we do not find widespread contamination of the ground-water environment."

It is an eerie paradox, and it is difficult to know how alarmed or reassured to feel. Certainly there is danger in breathing sighs of relief too soon. Just as the presence of a single cockroach in the kitchen sink speaks of the hundreds more behind the wall, periodic detections of contaminants in groundwater aquifers are often harbingers of widespread contamination yet to come. Groundwater flows both leisurely—sometimes only inches per year—and smoothly as it moves along the pores and cracks of the underground landscape. Without speed or turbulence, dispersion of chemical contaminants is also slow. Over time, an intermittent detection in one well can eventually become a constant detection in several. Moreover, even the merest trace of contamination can portend a serious problem if what is being detected is the bottom edge of a falling curtain of chemicals slowly moving its way down the aquifer's overlying substrate.

As a general rule, contamination in lowland areas of discharge—where aquifers give up their water to rivers and streams—is considered a lesser problem than contamination in the upland areas of recharge where aquifers receive rain and snow from the atmosphere. Areas of recharge are the headwaters of aquifers, and contamination here can fan out and fill the whole. In either case, once groundwater becomes contaminated, little can be done to remedy the problem. In contrast to the alfresco run of surface water, groundwater has no oxygen to hasten the breakdown of chemical contaminants nor open air

to facilitate the evaporation of solvents and other volatile organics. Contamination lingers in the still, watery vaults of aquifers.

* * *

With great pomp and flair, the city of Pekin passed its proposed groundwater protection ordinance in 1995. It has since been hailed as a model for the state. Essentially, the statute regulates land use in three recharge areas, each a narrow stretch of ground a mile or so long where the groundwater underneath flows into the city's wells. Additionally, the ordinance draws a two-thousand-foot ring of protection around each of the wellheads. Inside these seven circles, the city restricts, and in some cases prohibits, the siting of new businesses that handle large quantities of hazardous materials. Existing businesses are largely unaffected, although some have promised to make improvements.

Ever since the ordinance was drafted, personal knowledge about recharge, discharge, depth to water table, glacial deposits, and other details of hydrogeology has become a matter of civic pride in Pekin. Groundwater maps overlaid with a grid of the city's streets have appeared on the front page of the newspaper so that residents can locate themselves vis-à-vis the aquifer. The west end of Derby Street lies within a recharge area, for example, as do sections of Sabella, Charlotte, and Henrietta Streets. The east bluff does not. The owner of a gas station on Fourth Street, upon discovering himself inside one of the protected zones, pledged to install double-walled tanks to prevent leaks. He even praised the ordinance after attending a public hearing. "It's great, it should have been done years ago, and nobody paid attention to it."

Pekin's ordinance is a candle in the dark. It has sparked open discussion about the relationship between health and the environment, and it has lit in people's hearts new respect for the body of water they walk over and drink from. Its ability to safeguard the Sankoty Aquifer against the toxic activities that continue to go on ninety feet above it, however, is not at all clear. Toxic runoff from storm sewers empties into several creeks and at least one lake that overlay the recharge zone. And as the district superintendent of the water company points out, the rain itself contains pollutants. No local zoning laws can legislate against pesticide-laced raindrops or solvent-contaminated snowflakes falling in a recharge zone. Solutions to these problems need to be hammered out in chambers larger than small-town city councils.

In the meantime, industrial chemicals and pesticides persist in Pekin's drinking-water wells—sometimes making cameo appearances in Pekin's drinking-water wells—sometimes briefly exceeding their maximum contaminant levels, sometimes remaining well below the legal limit. They include benzene, perchloroethylene, 1,1,1-trichloroethane, the phthalate plasticizer DEHP, and a couple of lawn chemicals. This brings us to the present moment. We know the story of Sankoty Aquifer begins with a glacier. We know that someone, sooner or later, ends up drinking whatever poisons are spread on the earth above it. What happens next is the part of the story that is still unwritten.

About one-third of Americans draw their water from aquifers. The rest drink from rivers, lakes, and streams. Of course, ecologically speaking, everyone drinks from aquifers: all running surface water was at one time groundwater, aquifers being the mothers of rivers. As Rachel Carson pointed out, contamination of groundwater is, therefore, contamination of water everywhere.

Groundwater provides no archival photographs to consult. It offers no shores to walk along, no reflective surfaces to peer into, no fish, bivalves, grasses, or game birds to inquire about. Our relationship to aquifers is deeply biological, but it is not visual.

I once descended to the bottom of a well in order to look at groundwater in its natural habitat. This happened in Hawaii, where drinking water is drawn from a flattened lens of rain that is trapped under the island between the volcanic rock it trickled through and the Pacific Ocean beneath. (Freshwater floats on salt.) At the Halawa pumping station, I rode a cable car down a three-hundred-foot shaft to arrive in a blasted-out cavern filled with water. It was very dark and very quiet.

Illinois, I believe, would provide a more exotic underground landscape. In the descent, one could examine the mashed remains of preglacial forests, bluffs, dunes, islands, and cliffs. The bedrock floor would be inlaid with the trenches of ancestral riverbeds. The water table's undulating ceiling would offer a subdued reflection of the overlying topography.

Cultivating an ability to imagine these vast basins beneath us is an imperative need. What is required is a kind of mental divining rod that would connect this subterranean world to the images we see every day: a kettle boiling on the stove, a sprinkler bowing over the garden, a bathtub filling up. Our drinking water should not contain the fear of cancer. The presence of carcinogens in groundwater, no matter how faint, means we have paid too high a price for accepting the unimaginative way things are.