SILENT SPRING

RACHEL CARSON

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With essays by Edward O. Wilson and Linda Lear

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4. Surface Waters and Underground Seas

Of all our natural resources water has become the most precious. By far the greater part of the earth's surface is covered by its enveloping seas, yet in the midst of this plenty we are in want. By a strange paradox, most of the earth's abundant water is not usable for agriculture, industry, or human consumption because of its heavy load of sea salts, and so most of the world's population is either experiencing or is threatened with critical shortages. In an age when man has forgotten his origins and is blind even to his most essential needs for survival, water along with other resources has become the victim of his indifference.

The problem of water pollution by pesticides can be understood only in context, as part of the whole to which it belongs — the pollution of the total environment of mankind. The pollution entering our waterways comes from many sources: radioactive wastes from reactors, laboratories, and hospitals; fallout from nuclear explosions; domestic wastes from cities and towns; chemical wastes from factories. To these is added a new kind of fallout — the chemical sprays applied to croplands and gardens, forests and fields. Many of the chemical agents in this alarming mélange imitate and augment the harmful effects of radiation, and within the groups of chemicals themselves there are sinister and little-understood interactions, transformations, and summations of effect.

Ever since chemists began to manufacture substances that nature never invented, the problems of water purification have become complex and the danger to users of water has increased.

As we have seen, the production of these synthetic chemicals in large volume began in the 1940's. It has now reached such proportions that an appalling deluge of chemical pollution is daily poured into the nation's waterways. When inextricably mixed with domestic and other wastes discharged into the same water, these chemicals sometimes defy detection by the methods in ordinary use by purification plants. Most of them are so stable that they cannot be broken down by ordinary processes. Often they cannot even be identified. In rivers, a really incredible variety of pollutants combine to produce deposits that the sanitary engineers can only despairingly refer to as "gunk." Professor Rolf Eliassen of the Massachusetts Institute of Technology testified before a congressional committee to the impossibility of predicting the composite effect of these chemicals, or of identifying the organic matter resulting from the mixture. "We don't begin to know what that is," said Professor Eliassen. "What is the effect on the people? We don't know."

To an ever-increasing degree, chemicals used for the control of insects, rodents, or unwanted vegetation contribute to these organic pollutants. Some are deliberately applied to bodies of water to destroy plants, insect larvae, or undesired fishes. Some come from forest spraying that may blanket two or three million acres of a single state with spray directed against a single insect pest — spray that falls directly into streams or that drips down through the leafy canopy to the forest floor, there to become part of the slow movement of seeping moisture beginning its long journey to the sea. Probably the bulk of such contaminants are the waterborne residues of the millions of pounds of agricultural chemicals that have been applied to farmlands for insect or rodent control and have been leached out of the ground by rains to become part of the universal seaward movement of water.

Here and there we have dramatic evidence of the presence of these chemicals in our streams and even in public water supplies.

For example, a sample of drinking water from an orchard area in Pennsylvania, when tested on fish in a laboratory, contained enough insecticide to kill all of the test fish in only four hours. Water from a stream draining sprayed cotton fields remained lethal to fishes even after it had passed through a purifying plant, and in fifteen streams tributary to the Tennessee River in Alabama the runoff from fields treated with toxaphene, a chlorinated hydrocarbon, killed all the fish inhabiting the streams. Two of these streams were sources of municipal water supply. Yet for a week after the application of the insecticide the water remained poisonous, a fact attested by the daily deaths of goldfish suspended in cages downstream.

For the most part this pollution is unseen and invisible, making its presence known when hundreds or thousands of fish die, but more often never detected at all. The chemist who guards water purity has no routine tests for these organic pollutants and no way to remove them. But whether detected or not, the pesticides are there, and as might be expected with any materials applied to land surfaces on so vast a scale, they have now found their way into many and perhaps all of the major river systems of the country.

If anyone doubts that our waters have become almost universally contaminated with insecticides he should study a small report issued by the United States Fish and Wildlife Service in 1960. The Service had carried out studies to discover whether fish, like warm-blooded animals, store insecticides in their tissues. The first samples were taken from forest areas in the West where there had been mass spraying of DDT for the control of the spruce budworm. As might have been expected, all of these fish contained DDT. The really significant findings were made when the investigators turned for comparison to a creek in a remote area about 30 miles from the nearest spraying for budworm control. This creek was upstream from the first and separated from it by a high waterfall. No local spraying was known to have occurred. Yet these fish, too, contained DDT. Had the chemical reached this remote creek by hidden underground streams? Or had it been airborne, drifting down as fallout on the surface of the creek? In still another comparative study, DDT was found in the tissues of fish from a hatchery where the water supply originated in a deep well. Again there was no record of local spraying. The only possible means of contamination seemed to be by means of groundwater.

In the entire water-pollution problem, there is probably nothing more disturbing than the threat of widespread contamination of groundwater. It is not possible to add pesticides to water anywhere without threatening the purity of water everywhere. Seldom if ever does Nature operate in closed and separate compartments, and she has not done so in distributing the earth's water supply. Rain, falling on the land, settles down through pores and cracks in soil and rock, penetrating deeper and deeper until eventually it reaches a zone where all the pores of the rock are filled with water, a dark, subsurface sea, rising under hills, sinking beneath valleys. This groundwater is always on the move, sometimes at a pace so slow that it travels no more than 50 feet a year, sometimes rapidly, by comparison, so that it moves nearly a tenth of a mile in a day. It travels by unseen waterways until here and there it comes to the surface as a spring, or perhaps it is tapped to feed a well. But mostly it contributes to streams and so to rivers. Except for what enters streams directly as rain or surface runoff, all the running water of the earth's surface was at one time groundwater. And so, in a very real and frightening sense, pollution of the groundwater is pollution of water everywhere.

It must have been by such a dark, underground sea that poisonous chemicals traveled from a manufacturing plant in Colorado to a farming district several miles away, there to poison wells, sicken humans and livestock, and damage crops — an extraordinary episode that may easily be only the first of many like it. Its history, in brief, is this. In 1943, the Rocky Mountain Arsenal of the Army Chemical Corps, located near Denver, began to manufacture war materials. Eight years later the facilities of the arsenal were leased to a private oil company for the production of insecticides. Even before the change of operations, however, mysterious reports had begun to come in. Farmers several miles from the plant began to report unexplained sickness among livestock; they complained of extensive crop damage. Foliage turned yellow, plants failed to mature, and many crops were killed outright. There were reports of human illness, thought by some to be related.

The irrigation waters on these farms were derived from shallow wells. When the well waters were examined (in a study in 1959, in which several state and federal agencies participated) they were found to contain an assortment of chemicals. Chlorides, chlorates, salts of phosphonic acid, fluorides, and arsenic had been discharged from the Rocky Mountain Arsenal into holding ponds during the years of its operation. Apparently the groundwater between the arsenal and the farms had become contaminated and it had taken 7 to 8 years for the wastes to travel underground a distance of about 3 miles from the holding ponds to the nearest farm. This seepage had continued to spread and had further contaminated an area of unknown extent. The investigators knew of no way to contain the contamination or halt its advance.

All this was bad enough, but the most mysterious and probably in the long run the most significant feature of the whole episode was the discovery of the weed killer 2,4-D in some of the wells and in the holding ponds of the arsenal. Certainly its presence was enough to account for the damage to crops irrigated with this water. But the mystery lay in the fact that no 2,4-D had been manufactured at the arsenal at any stage of its operations.

After long and careful study, the chemists at the plant concluded that the 2,4-D had been formed spontaneously in the open basins. It had been formed there from other substances discharged from the arsenal; in the presence of air, water, and sunlight, and quite without the intervention of human chemists, the holding ponds had become chemical laboratories for the production of a new chemical — a chemical fatally damaging to much of the plant life it touched.

And so the story of the Colorado farms and their damaged crops assumes a significance that transcends its local importance. What other parallels may there be, not only in Colorado but wherever chemical pollution finds its way into public waters? In lakes and streams everywhere, in the presence of catalyzing air and sunlight, what dangerous substances may be born of parent chemicals labeled "harmless"?

Indeed one of the most alarming aspects of the chemical pollution of water is the fact that here — in river or lake or reservoir, or for that matter in the glass of water served at your dinner table — are mingled chemicals that no responsible chemist would think of combining in his laboratory. The possible interactions between these freely mixed chemicals are deeply disturbing to officials of the United States Public Health Service, who have expressed the fear that the production of harmful substances from comparatively innocuous chemicals may be taking place on quite a wide scale. The reactions may be between two or more chemicals, or between chemicals and the radioactive wastes that are being discharged into our rivers in ever-increasing volume. Under the impact of ionizing radiation some rearrangement of atoms could easily occur, changing the nature of the chemicals in a way that is not only unpredictable but beyond control.

It is, of course, not only the groundwaters that are becoming contaminated, but surface-moving waters as well — streams, rivers, irrigation waters. A disturbing example of the latter seems to be building up on the national wildlife refuges at Tule Lake and Lower Klamath, both in California. These refuges are part of a chain including also the refuge on Upper Klamath Lake just over the border in Oregon. All are linked, perhaps fatefully, by a shared water supply, and all are affected by the fact that they lie like small islands in a great sea of surrounding farmlands — land reclaimed by drainage and stream diversion from an original waterfowl paradise of marshland and open water.

These farmlands around the refuges are now irrigated by water from Upper Klamath Lake. The irrigation waters, recollected from the fields they have served, are then pumped into Tule Lake and from there to Lower Klamath. All of the waters of the wildlife refuges established on these two bodies of water therefore represent the drainage of agricultural lands. It is important to remember this in connection with recent happenings.

In the summer of 1960 the refuge staff picked up hundreds of dead and dying birds at Tule Lake and Lower Klamath. Most of them were fish-eating species — herons, pelicans, grebes, gulls. Upon analysis, they were found to contain insecticide residues identified as toxaphene, DDD, and DDE. Fish from the lakes were also found to contain insecticides; so did samples of plankton. The refuge manager believes that pesticide residues are now building up in the waters of these refuges, being conveyed there by return irrigation flow from heavily sprayed agricultural lands.

Such poisoning of waters set aside for conservation purposes could have consequences felt by every western duck hunter and by everyone to whom the sight and sound of drifting ribbons of waterfowl across an evening sky are precious. These particular refuges occupy critical positions in the conservation of western waterfowl. They lie at a point corresponding to the narrow neck of a funnel, into which all the migratory paths composing what is known as the Pacific Flyway converge. During the fall migration they receive many millions of ducks and geese from nesting grounds extending from the shores of Bering Sea east to Hudson Bay — fully three fourths of all the waterfowl that move south into the Pacific Coast states in autumn. In summer they provide nesting areas for waterfowl, especially for two endangered species, the redhead and the ruddy duck. If the lakes and pools of these refuges become seriously contaminated, the damage to the waterfowl populations of the Far West could be irreparable.

Water must also be thought of in terms of the chains of life it supports — from the small-as-dust green cells of the drifting plant plankton, through the minute water fleas to the fishes that strain plankton from the water and are in turn eaten by other fishes or by birds, mink, raccoons — in an endless cyclic transfer of materials from life to life. We know that the necessary minerals in the water are so passed from link to link of the food chains. Can we suppose that poisons we introduce into water will not also enter into these cycles of nature?

The answer is to be found in the amazing history of Clear Lake, California. Clear Lake lies in mountainous country some 90 miles north of San Francisco and has long been popular with anglers. The name is inappropriate, for actually it is a rather turbid lake because of the soft black ooze that covers its shallow bottom. Unfortunately for the fishermen and the resort dwellers on its shores, its waters have provided an ideal habitat for a small gnat, *Chaoborus astictopus*. Although closely related to mosquitoes, the gnat is not a bloodsucker and probably does not feed at all as an adult. However, human beings who shared its habitat found it annoying because of its sheer numbers. Efforts were made to control it but they were largely fruitless until, in the late 1940's, the chlorinated hydrocarbon insecticides offered new weapons. The chemical chosen for a fresh attack was DDD, a close relative of DDT but apparently offering fewer threats to fish life.

The new control measures undertaken in 1949 were carefully planned and few people would have supposed any harm could result. The lake was surveyed, its volume determined, and the insecticide applied in such great dilution that for every part of chemical there would be 70 million parts of water. Control of the gnats was at first good, but by 1954 the treatment had to be repeated, this time at the rate of 1 part of insecticide in 50 million parts of water. The destruction of the gnats was thought to be virtually complete.

The following winter months brought the first intimation that other life was affected: the western grebes on the lake began to die, and soon more than a hundred of them were reported dead. At Clear Lake the western grebe is a breeding bird and also a winter visitant, attracted by the abundant fish of the lake. It is a bird of spectacular appearance and beguiling habits, building its floating nests in shallow lakes of western United States and Canada. It is called the "swan grebe" with reason, for it glides with scarcely a ripple across the lake surface, the body riding low, white neck and shining black head held high. The newly hatched chick is clothed in soft gray down; in only a few hours it takes to the water and rides on the back of the father or mother, nestled under the parental wing coverts.

Following a third assault on the ever-resilient gnat population, in 1957, more grebes died. As had been true in 1954, no evidence of infectious disease could be discovered on examination of the dead birds. But when someone thought to analyze the fatty tissues of the grebes, they were found to be loaded with DDD in the extraordinary concentration of 1600 parts per million.

The maximum concentration applied to the water was $1/50$ part per million. How could the chemical have built up to such prodigious levels in the grebes? These birds, of course, are fish eaters. When the fish of Clear Lake also were analyzed the picture began to take form — the poison being picked up by the smallest organisms, concentrated and passed on to the larger predators. Plankton organisms were found to contain about 5 parts per million of the insecticide (about 25 times the maximum concentration ever reached in the water itself); plant-eating fishes had built up accumulations ranging from 40 to 300 parts per million; carnivorous species had stored the most of all. One, a brown bullhead, had the astounding concentration of 2500 parts per million. It was a house-that-Jack-built sequence, in which the large carnivores had eaten the smaller carnivores, that had eaten the herbivores, that had eaten the plankton, that had absorbed the poison from the water.

Even more extraordinary discoveries were made later. No trace of DDD could be found in the water shortly after the last application of the chemical. But the poison had not really left the lake; it had merely gone into the fabric of the life the lake supports. Twenty-three months after the chemical treatment had ceased, the plankton still contained as much as 5.3 parts per million. In that interval of nearly two years, successive crops of plankton had flowered and faded away, but the poison, although no longer present in the water, had somehow passed from generation to generation. And it lived on in the animal life of the lake as well. All fish, birds, and frogs examined a year after the chemical applications had ceased still contained DDD. The amount found in the flesh always exceeded by many times the original concentration in the water. Among these living carriers were fish that had hatched nine months after the last DDD application, grebes, and California gulls that had built up concentrations of more than 2000 parts per million. Meanwhile, the nesting colonies of the grebes dwindled — from more than 1000 pairs before the first insecticide treatment to about 30 pairs in 1960. And even the thirty seem to have nested in vain, for no young grebes have been observed on the lake since the last DDD application.

This whole chain of poisoning, then, seems to rest on a base of minute plants which must have been the original concentrators. But what of the opposite end of the food chain — the human being who, in probable ignorance of all this sequence of events, has rigged his fishing tackle, caught a string of fish from the waters of Clear Lake, and taken them home to fry for his supper? What could a heavy dose of DDD, or perhaps repeated doses, do to him?

Although the California Department of Public Health professed to see no hazard, nevertheless in 1959 it required that the use of DDD in the lake be stopped. In view of the scientific evidence of the vast biological potency of this chemical, the action seems a minimum safety measure. The physiological effect of DDD is probably unique among insecticides, for it destroys part of the adrenal gland — the cells of the outer layer known as the adrenal cortex, which secretes the hormone cortin. This destructive effect, known since 1948, was at first believed to be confined to dogs, because it was not revealed in such experimental animals as monkeys, rats, or rabbits. It seemed suggestive, however, that DDD produced in dogs a condition very similar to that occurring in man in the presence of Addison's disease. Recent medical research has revealed that DDD does strongly suppress the function of the human adrenal cortex. Its cell-destroying capacity is now clinically utilized in the treatment of a rare type of cancer which develops in the adrenal gland.

The Clear Lake situation brings up a question that the public needs to face: Is it wise or desirable to use substances with such strong effect on physiological processes for the control of insects, especially when the control measures involve introducing the chemical directly into a body of water? The fact that the insecticide was applied in very low concentrations is meaningless, as its explosive progress through the natural food chain in the lake demonstrates. Yet Clear Lake is typical of a large and growing number of situations where solution of an obvious and often trivial problem creates a far more serious but conveniently less tangible one. Here the problem was resolved in favor of those annoyed by gnats, and at the expense of an unstated, and probably not even clearly understood, risk to all who took food or water from the lake.

It is an extraordinary fact that the deliberate introduction of poisons into a reservoir is becoming a fairly common practice. The purpose is usually to promote recreational uses, even though the water must then be treated at some expense to make it fit for its intended use as drinking water. When sportsmen of an area want to "improve" fishing in a reservoir, they prevail on authorities to dump quantities of poison into it to kill the undesired fish, which are then replaced with hatchery fish more suited to the sportsmen's taste. The procedure has a strange, Alice-in-Wonderland quality. The reservoir was created as a public water supply, yet the community, probably unconsulted about the sportsmen's project, is forced either to drink water containing poisonous residues or to pay out tax money for treatment of the water to remove the poisons — treatments that are by no means foolproof.

As ground and surface waters are contaminated with pesticides and other chemicals, there is danger that not only poisonous but also cancer-producing substances are being introduced into public water supplies. Dr. W. C. Hueper of the National Cancer Institute has warned that "the danger of cancer hazards from the consumption of contaminated drinking water will grow considerably within the foreseeable future." And indeed a study made in Holland in the early 1950's provides support for the view that polluted waterways may carry a cancer hazard. Cities receiving their drinking water from rivers had a higher death rate from cancer than did those whose water came from sources presumably less susceptible to pollution such as wells. Arsenic, the environmental substance most clearly established as causing cancer in man, is involved in two historic cases in which polluted water supplies caused widespread occurrence of cancer. In one case the arsenic came from the slag heaps of mining operations, in the other from rock with a high natural content of arsenic. These conditions may easily be duplicated as a result of heavy applications of arsenical insecticides. The soil in such areas becomes poisoned. Rains then carry part of the arsenic into streams, rivers, and reservoirs, as well as into the vast subterranean seas of groundwater.

Here again we are reminded that in nature nothing exists alone. To understand more clearly how the pollution of our world is happening, we must now look at another of the earth's basic resources, the soil.

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ERICH HARTMANN/MAGNUM PHOTOS

RACHEL CARSON (1907–1964) spent most of her professional life as a marine biologist with the U.S. Fish and Wildlife Service. By the late 1950s, she had written three lyrical, popular books about the sea, including the best-selling *The Sea Around Us*, and had become the most respected science writer in America. She completed *Silent Spring* against formidable personal odds and despite critical attacks that echoed the assault on Charles Darwin when he published *The Origin of Species*, and with it shaped a powerful social movement that has altered the course of history.

Despite the enormous impact of *Silent Spring*, Carson remained modest about her accomplishment; as she wrote to a friend, "The beauty of the living world I was trying to save has always been uppermost in my mind—that, and anger at the senseless, brutish things that were being done . . . Now I can believe I have at least helped a little."

Among the many honors and awards Carson received during her lifetime were the National Book Award, for *The Sea Around Us* (1951); a Guggenheim fellowship (1951–1952); the John Burroughs Medal (1952); the Henry G. Bryant Gold Medal (1952); the Women's National Book Association Constance Lindsay Skinner Award (1963); the Conservationist of the Year Award from the National Wildlife Federation (1963); and a Gold Medal from the New York Zoological Society (1963).

Rachel Carson lived in Silver Spring, Maryland, until her untimely death.

FROM THE INTRODUCTION BY LINDA LEAR

In *Silent Spring,* and later in testimony before a congressional committee, Rachel Carson asserted that one of the most basic human rights must surely be the "right of the citizen to be secure in his own home against the intrusion of poisons applied by other persons." Through ignorance, greed, and negligence, government had allowed "poisonous and biologically potent chemicals" to fall "indiscriminately into the hands of persons largely or wholly ignorant of their potentials for harm." When the public protested, it was "fed little tranquillizing pills of half-truth" by a government that refused to take responsibility for or acknowledge evidence of damage. Carson challenged such moral vacuity. "The obligation to endure," she wrote, "gives us the right to know."

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