Kepone — A Case Study of an Environmental Legacy

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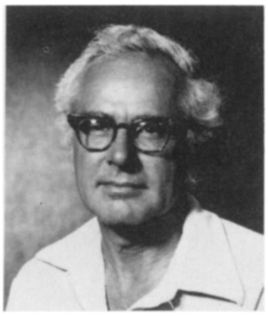

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The decade of the 1970s saw passage of some of the most far-reaching environmental legislation of the century. Much of this legislation dealt with toxic substances and wastes which may affect the health of humans and damage various ecosystem components. Some of these major acts and their areas of coverage are reviewed in table 1. Many of the acts are still in the process of implementation and their full impact on industry and the general public will be felt in the 1980s.

Despite this spate of legislation, environmental insults continue, e.g., releases of polychlorinated biphenyls (PCB's) to the environment; contamination of poultry sold in the market place by PCB's; releases of toxic substances to the environment as the result of transportation accidents; leaking of toxic wastes from old disposal sites; and the potential danger of dioxins which are present as low-level contaminants in certain herbicides.

It is interesting to consider why the insults continue in spite of the legislation of the 1970s. The story of the insecticide Kepone is instructive in this regard.

The Kepone Story

In October 1977, a federal district judge in Richmond, Virginia fined Allied Chemical Company more than $13 million. Allied Chemical and its subsidiary, Life Science Products (LSP), were defendants in suits involving about $200 million in damages filed by former plant employees. Allied pled no contest to 940 counts of pollution relating to the insecticide Kepone and its release into the James River from its plant in Hopewell, Virginia. However, Allied was cleared of the charge that they participated with their subsidiary in the pollution of the river. Life Science Products had taken over the Hopewell plant and supplied Allied with Kepone. The major pollution events occurred at Life Science. The civil suits were brought by the workers who suffered neurological disturbances, tremors, and visual impairments brought about as a result of exposure to Kepone. Suits also involved fishermen who suffered financial loss as a result of closing the James River to fishing (*Environment* 1977).

Workers were exposed to high levels of Kepone for many months. High levels were found in their blood and fat along with the neurological symptoms and clinical toxicity to the liver and testes (Boylan *et al.*, 1977).

The problem was first diagnosed by a Hopewell physician who treated one of the plant's employees. He suspected that exposure to Kepone was causing the patient's tremors and sent a blood sample to the U.S. Public Health Service Center for Disease Control in Atlanta. They found Kepone to be present at a level of 7.5 ppm (parts per million) in the blood samples. The State Health Department then interviewed and examined all plant employees on July 23, 1975. Seventy out of 150 workers displayed toxicity symptoms and 30 were hospitalized. Some workers had also exposed their families

TABLE 1. Legislation, Responsible Agency, and Materials Covered By Recent Acts Dealing with Toxic Substances.

Statute	*Materials Covered and Administrator*
Toxic Substances Control Act (TSCA) 1976	Pre-manufacture evaluation of all new chemicals except food, food additives, drugs, pesticides, alcohol, and tobacco; regulation of a new chemical from inception through disposal; specific regulation of PCB's. (U.S. EPA)
Clean Air Act (CAA) 1972	Regulation of hazardous air pollutants. (U.S. EPA)
Federal Water Pollution Control Act (FWPCA) 1972	Regulation of toxic water pollutants; updated and amended 1977 and 1978 and now called collectively the Clean Water Act. (U.S. EPA)
Safe Drinking Water Act (SDWA) 1974	Regulation of and setting of uniform national standards for drinking water contaminants. (U.S. EPA)
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 1972 (first passed 1947)	Regulation and licensing of pesticides. (U.S. EPA)
Resource Conservation and Recovery Act (RCRA) 1976	Regulation of hazardous wastes. (U.S. EPA)
Occupational Safety and Health Act (OSHA) 1970	Protection of workers from and regulation of toxic chemicals in the work place. (OSHA)
Federal Hazardous Substance Act (FHSA) 1970	Regulation of "toxic" household products. (CPSC)

to Kepone which was present in dust on their clothes (Sterrett and Boss 1977). Allied Chemical settled almost all of the suits, reaching out-of-court agreements with 30 workers, 8 wives of employees, and 12 employees' children who claimed exposure to Kepone.

From 1966 to 1975, Kepone was discharged into the James River estuary at Hopewell. At one period the effluent containing Kepone inhibited bacterial processes involved in the breakdown of sewage and put the waste treatment plant out of operation. The discharges then went untreated into the James River.

TABLE 2. Production Amounts and Uses of Kepone

1. Used as a control for banana and potato bugs in foreign countries.
2. Formerly used in roach and ant poisons within the U.S.
3. 90-95% of U.S. production goes to foreign markets.
4. Life Science Products produced about 771,000 kg in 16 months during 1974-75.
5. Allied Chemical produced about 680,000 kg between 1966-74 at its Semi-Works Plant.
6. Maximum allowable level in roach traps was 0.125%.

Source: Lunsford *et al.* 1980.

Production/Amounts Released

Little Kepone was used in the United States and the bulk of the product produced by Life Science Products over its 16-month period of operation was sent to Latin America, Europe, and Africa. Pertinent production information is given in table 2. Prior to this time, from 1966 to 1974, production was at Allied Chemical's Semi-Works Plant (Lunsford *et al.*, 1980). Battelle Corporation estimated in 1978 that 90,720 kg of the insecticide were released into the environment as emissions to air, discharge of wastewaters, and bulk-disposal of off-specification batches (Lunsford *et al.*, 1980).

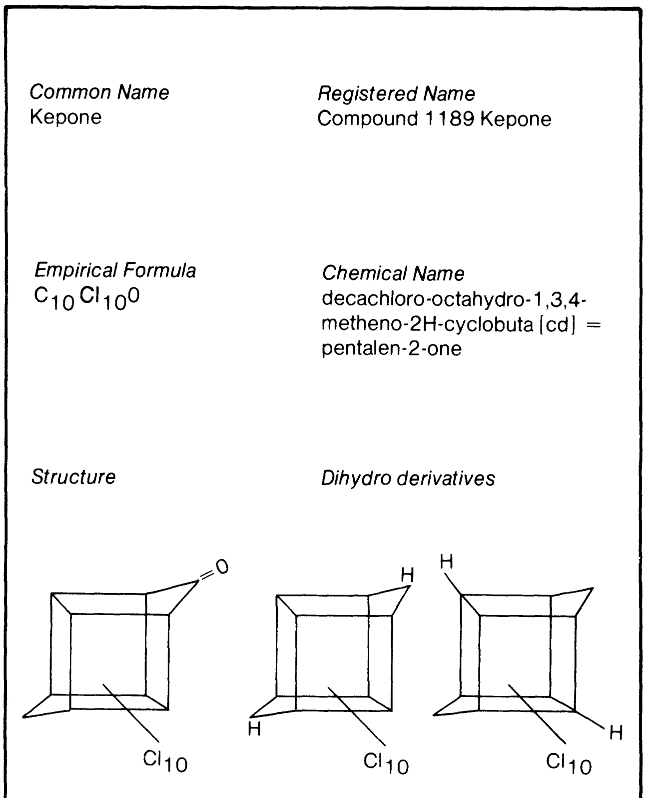

FIGURE 1. Common name, registered name, empirical formula, chemical name, structure, and two dihydro derivatives of Kepone.

Chemistry

Kepone (chlordecone) is a chlorinated hydrocarbon pesticide similar to chlordane, aldrin, dieldrin, and endrin (Sterrett and Boss 1977). The common name, registered name, empirical formula, chemical name, structure, and two dihydro derivatives are given in figure 1. Chemical properties are given in table 3.

Kepone has a low vapor pressure and degrades very slowly in the environment. It shares a cage-like structure with Mirex and both are powerful pesticides. Kepone is a degradation product of Mirex (Carlson, Konyha, and Wheeler 1976). Kepone has a strong affinity for lipids and would be expected to display biomagnification through food chains. Mirex is known to persist for at least 12 years in soil, so we would expect Kepone to be very persistent in the environment (Sterrett and Boss 1977).

Toxicology

The workers were exposed to a Kepone concentration in the plant atmosphere of 3 mg/m^3. In rats a six-month LD-50 of 1.5 mg/kg/day was reported by Jaeger (1976). He stated that the workers received a daily dose which was only a factor of 12.5 lower than the six-month LD-50 in rats.

The rabbit is the *most sensitive* species, and the LD-50 was reached at a dosage level of 65 mg/kg or 65 ppm, about nine times greater than the blood level of Kepone found in the Life Science Products workers (7.5 ppm).

Cancer is another consideration. Studies sponsored by Allied Chemical and conducted by the National Cancer Institute (NCI) found that 10 ppm Kepone in the diet caused cancer in rats and mice. This amount is within a factor of 5 of the daily dose probably absorbed by the employees (Jaeger 1976). Some of the workers were exposed for 15 months and they should be closely followed to determine if an increased incidence of cancer occurs.

TABLE 3. Chemical Properties of Kepone.

1. Pure compound a white powder.
2. Decomposes at 350°C.
3. Slightly soluble in water.
4. Slightly soluble in hydrocarbon solvents.
5. Soluble in alcohol, ketones, and acetic acid.
6. Carbonyl group suggests hydrate formation in aqueous solutions.
7. Exists in diol form in aqueous and in nonpolar organic solvents such as hexane and benzene.
8. Forms hemiacetal structure in methanol.
9. Low vapor pressure.
10. A cage compound.

Source: Saleh and Lee, 1978 and Sterrett and Boss 1977.

The effects of Kepone on mammals are summarized in table 4. Many workers at Life Science Products displayed the same symptoms found in animals.

Distribution in the Environment

The U.S. Environmental Protection Agency (EPA) maintained an air monitoring station about 200 yards from the Science Products plant. Monitoring activity between March 1974 and April 1975 revealed that Kepone made up 40% airborne particulates. Concentrations in ice samples from a nearby ice plant ranged from 0.1 to 1.0 ppm.

A collection box at Life Science Products had cracks in a drainpipe connected to it that allowed Kepone to seep into the Hopewell sewer system during the 1974-75 period. This material was discharged into the James River. As the result of this discharge and others to the James River which eventually reached Chesapeake Bay, Kepone became widely distributed in the environment.

A summary of levels of Kepone found in the environment is given in table 5. Concentrations of Kepone residues were at or above 0.02 $\mu g/l$ in all reaches of the river (Lunsford *et al.*, 1980). These are trace amounts and do not represent acute toxicological hazard to animals. However, levels above 0.02 $\mu g/l$ can lead to bioconcentration by finfish to levels that exceed the FDA allowable maximum in fish tissues of 0.30 $\mu g/l$ (Battelle 1978). Kepone levels in phytoplankton also reached concentrations above that found in the water. Sediment levels reached several orders of magnitude above water levels, particularly in river sediments near Hopewell and would be expected to provide a source of Kepone to contaminate organisms for years. Although groundwater levels were generally low, levels were high in seeps at the sewage treatment plant lagoons.

In 1947 Congress passed FIFRA which required registration with USDA of pesticides distributed in interstate commerce. However, the Secretary of Agriculture had no power to refuse registration of a chemical even though it might be highly dangerous (Miller 1978). Kepone was first registered as a pesticide with the USDA in 1959. There was relatively little toxicological informa-

TABLE 4. Effects of Kepone in Mammals.

1. Highest levels are found in the liver and lowest levels are found in the muscle tissue based upon rat studies.
2. Disrupts ion movement across axonal membranes of nerves; inhibits enzymatic function of ATPase; inhibits enzymatic role of lactate dehydrogenase in rabbit muscle.
3. Symptoms include: tremors, ataxia, skin changes, hyperexcitability, hyperactivity, muscle spasm, testicular atrophy, low sperm count, estrogenic effects, sterility, breast enlargement, liver lesions, and cancer.

Source: Sterrett and Boss 1977.

TABLE 5. Distribution of Kepone in the Environment.

Material	*Location*	*Level*
Water column	James River—all reaches	ND-1.20
Phytoplankton	James River—estuary	ND-2.06 μg/g
Sediments	James River—above Hopewell	<0.02 μg/g
Sediments	James River tributary—at sewage treatment plant	1.0-9.99 μg/g
Sediments	James River—lower river to Chesapeake Bay	ND-0.61 μg/g
Finfish	James River—averages for all species	0.006-1.42 μg/g
Groundwater	Observation wells in Hopewell area	ND-26 μg/1
Groundwater	Seeps at Hopewell primary sewage treatment plant lagoon	ND-395 μg/1

Source: Lunsford *et al.*, 1980.

tion available, but it was stated at the time of registration that Kepone causes "DDT-like tremors." Allied Chemical Corporation had contracted with the Medical College of Virginia in 1958 to assess the acute, subchronic, and chronic toxicity of Kepone. This information was included in the petitions for registration; this information, however, was confidential (Jaeger 1976). Jaeger does point out that Allied Chemical did release some information on acute toxicity, but not on chronic toxicity.

In 1966, Allied Chemical began to manufacture Kepone at Hopewell. During the 1960s, two investigations on the subchronic toxicity of Kepone appeared and indicated that the chemical produces ataxia and tremors in mice. The main body of toxicity information was not released by Allied Chemical until the court cases of the mid-1970s.

FIFRA emphasized proper labeling and efficacy of pesticides shipped in interstate commerce. 1972 amendments simplified registration and corrected inequities. Legal authority was strengthened and more explicit requirements for premarket testing of new products for human health effects and hazard to the environment were required. EPA was charged with looking at previously registered products to determine whether they met new standards (CEQ 1979). Also, EPA had assumed responsibility in 1972 for pesticides registered and regulated under the USDA.

Although it is difficult to look back and determine whether the "whistle" should have been blown on Kepone, we can think back to 1959 when Kepone was registered as a time before the period of questioning the safety of pesticides during the environmental movement of the 1960s. Allied Chemical apparently handled the product in a safe manner, and even though EPA was admonished to reexamine previous pesticides, there were some 40,000 already on the market and the review process was slow and cumbersome. Even if the public had been alerted to possible problems with Kepone, they would not have had access to the toxicological data.

Two very interesting events concerning Kepone occurred in the early 1970s. The first event was associated with NCI testing the toxicity of Kepone in mice in November 1971 and in rats in May 1972. The mice were killed in August 1973 and the rats in July 1974. Results were not released until April 1976 (Jaeger 1976). The second event was the cessation of Kepone manufacturing by Allied Chemical in 1973, and the incorporation of Life Science Products in Virginia. LSP contracted with Allied Chemical to produce Kepone from raw materials supplied by Allied and the product was to be sold exclusively to Allied (CEQ 1976). Sterrett and Boss (1977) pointed out that two former executives of Allied ran LSP and that the plant was an "old converted gas station" near the Allied Chemical plant on the James River.

The start of a new company could have been a time for review of Kepone by EPA administrators under FIFRA, but, as mentioned earlier, there were about 40,000 pesticides already marketed that would have to be reviewed—a staggering task for any administrator. In the 1972 amendment to FIFRA the phrase "unreasonable adverse effects on the environment" was added to the criteria for registration. Had EPA reviewed the case, they would have found little available information in this regard. By 1972, companies were required to supply test data regarding potential health and environmental impact. Lack of data, however, did contribute indirectly to the lack of action against Kepone because there was no indication of "imminent hazard" that would lead to suspension. Another indirect cause contributing to lack of action on Kepone might have been the clause in FIFRA which excluded U.S. exports from the Act except for certain recordkeeping requirements (Miller 1978). Remember that much of the Kepone was exported.

Another point in the process where Kepone could have been reviewed was in October 1973 when the city of Hopewell applied to the Water Control Board for a permit to discharge municipal waste water. They claimed that no industrial discharges would enter the sewage treatment plant. Remember that Kepone was discharged into the James River between 1966 and 1975. The Federal Water Pollution Control Act (FWPCA) amendments of 1972 could have been applied at that time. In preparing the 1972 Act, Congress had recognized that toxic pollutants required special and stringent controls. FWPCA defined toxic pollutants as those which "on the basis of information available to the administrator, cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions . . . or physical deformation" in organisms (Izaak Walton League 1973). EPA was to prepare a list of toxic pollutants and establish standards for them. It is understandable that provisions of the FWPCA were not applied because of the lag time between passage of an act and the working out of the details for administering the act. In this case, serious regulation of toxic pollutants in water didn't occur until after passage of the Clean Water Act Amendments in 1977 and 1978. Although Kepone would have fit the definition of a toxic pollutant under the FWPCA in 1973, the really clinching data that Kepone causes cancer in laboratory animals was not released until 1976.

The public was not yet fully aware in 1973 that cancer-causing agents were present in water. This awareness occurred very suddenly in 1974 as the result of a study indicating a possible correlation between incidence of cancer in New Orleans residents and drinking of treated water from the Mississippi River, and the release of a survey by EPA indicating that the problem of organic pollutants in water might be a national one.

The Kepone problem resulted from the careless nature of operation of the LSP plant at Hopewell. Sterrett and Boss (1977) point out that Allied Chemical had listed detailed safety rules for manufacturing Kepone in a memorandum. However, LSP was conducting a very dirty operation.

LSP was cited for failing to obtain an air pollution permit. In February 1974 LSP applied for and received a permit. As cited earlier, air monitoring showed that Kepone made up 40% of particulate material in the nearby atmosphere. By October 1974, LSP was required to install a baghouse.

Meanwhile, LSP was apparently leaking more than usual amounts of Kepone into the city sewers because the sewage treatment plant malfunctioned and raw sewage was entering the James River. Kepone had destroyed the bacterial digester. The City of Hopewell then (April) requested toxicity and treatment information from EPA. In November 1974 EPA complied with the request and gave the Water Control Board the toxicity information then available and recommended that a limit of 0.4 ppm Kepone be allowed in the input water to the sewage plant. This is strange because in the original application, the treatment plant claimed to the board that there were no industrial chemical discharges entering the sewage plant.

At about the same time (September), a former employee filed a complaint about working conditions at LSP under provisions of the Occupational Safety and Health Administration (OSHA). OSHA reviewed the available toxicity information and concluded that there was no severe hazard so the complaint was handled as a discrimination case.

In March 1975, Allied Chemical applied for registration of Kepone under FIFRA as the result of expected new regulations. EPA began to investigate in March 1975 whether or not LSP had violated the FIFRA regulation that all pesticide products and producers register with EPA. On April 11, 1975, Allied Chemical notified EPA that Kepone need not be registered because it was only a pesticide component. Finally, in July 1975, the State of Virginia amended the Hopewell's waste water permit to require LSP to pretreat its effluents entering the treatment plant—LSP seemed to ignore this requirement. By now it was clear that a severe problem existed and the State of Virginia Health Department ordered LSP to stop production in July 1975. The "stop" order did allow for limited production into September. In May 1976, Allied Chemical, Life Sciences, and the City of Hopewell were indicted on 1,096 criminal counts, including defrauding of EPA and violations of federal water pollution laws (CEQ 1976).

Summary

In spite of government, state, and local agencies and regulations, hazardous substances still reach the environment and endanger human health. The Kepone story is instructive; the main contributing factors are reviewed below:

1. Registration in the early days under the USDA did not prevent a hazardous substance from reaching the market.
2. Toxicological information at the time of registration was not generally available to the public.
3. The apparent unwillingness of a corporation to express caution in regard to a chemical even after it had toxicological data. (Monsanto in 1971 undertook a voluntary ban against manufacture of PCB's for use in unenclosed systems.)
4. The difficult task facing a regulatory agency to look back and review some 40,000 pesticide products already on the market.
5. The slowness of the National Cancer Institute to release its findings.
6. The inadequacy of the permit system for discharging waste water and the lack of knowledge regarding whether or not Kepone was present in effluent entering the plant.
7. The long lag times between passage of federal legislation and its implementation by a regulatory agency.
8. The lack of recognition by any agency of the work conditions at LSP.

The Kepone event not only led to human damage but threatened the environment on a broad scale and continues to represent an environmental hazard. What can be done to prevent these disasters? Miller (1978) points out that one agency administrator responded to criticism by saying, "we could accomplish a great deal if we were able to keep track of what toxic chemicals are entering our environment." Although Kepone was evaluated and registered, the screening process could be improved by giving special attention under FIFRA, to chemicals that display 1) persistence in the environment, and 2) bioconcentration. These two characteristics plus the usual health hazard information should raise considerable doubt concerning continued use of a substance. In our opinion, pesticides that display persistence or bioconcentration, or which cause cancer in laboratory animals should be banned. Does FIFRA do this? No, it does not!

It is not possible in this article to review the FIFRA legislation and its many amendments. The act results from a very complex interaction of social and institutional forces that lead to what is called the "Balancing Test" (Miller 1978). These forces presently prevent an outright ban unless other factors are taken into account such as a balance between beneficial uses and risks. Under FIFRA a substance can be suspended for use if it can be shown that the risk to the environment far outweighs the factor of beneficial use. But all of this is not clear cut. If the act were changed to read that use of pesticides that show persistence, bioconcentration, or cause cancer in laboratory animals be suspended from use, an administrator might better be able to evaluate toxics reaching the environment today. Continued use of the "Balancing Test" will not always lead to protection of the environment and human health.

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Crisis in Science Education

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3. Provide that every elementary school in the nation has at least one teacher who specializes in teaching science.

4. Establish the national expectation that students are exposed to some science instruction every school day of their K-12 school careers.

5. Establish funding so that salaries of the most capable science and mathematics teachers are competitive with salaries provided by industry.

6. Establish minimal (but high quality) standards for the pre-service science and mathematics preparation for teachers at all levels.

7. Provide opportunities for continuing in-service education in science and mathematics for all elementary teachers and teachers of junior high and high school science and mathematics.

8. Establish procedures for national recognition of schools, curricula, students, and teachers who exemplify excellence in science and mathematics education.

9. Develop public relations programs emphasizing the need for parental involvement in childrens' education, stressing the need for scientific literacy for future citizens.

10. Encourage non-school programs that foster interest in science and mathematics (museums, interactive science centers, science "olympics" competitions, science-oriented TV programs, traveling science shows for youngsters).

Alan J. McCormack, *editor*