

The Vinyl

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Danger of chemical carcinogens in the environment is becoming increasingly apparent. Widespread exposure to numerous synthetic substances and the fact that cancer does not appear until many years after exposure to a carcinogen make carcinogenesis difficult to detect and often almost impossible to assign unequivocally to a particular compound. Screening tests are expensive, time-consuming, and results are often suspect (7). The story of vinyl chloride illustrates some of these problems.

Vinyl chloride is a colorless gas at ordinary temperatures and pressures, but in industry it is usually handled as liquid under pressure in steel cylinders. It is used as a precursor to the sulfa drugs and, despite its flammability, narcotic effect, and tendency to form solid polymers, as a refrigerant and as a propellant for aerosol sprays. But by far the major use of vinyl chloride is to make vinyl plastics.

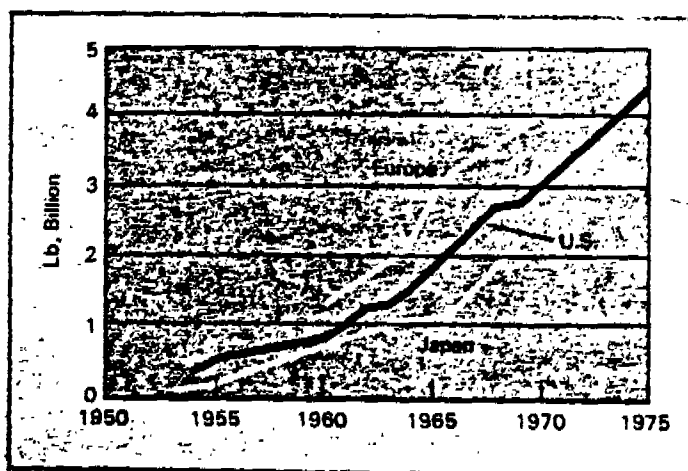


Figure 1. Consumption of polyvinyl chloride plastics. One pound equals 0.45 kg

First step in vinyl plastic production is to synthesize vinyl chloride monomer (VCM), usually from ethylene or acetylene; plants where this is done are usually located close to petroleum refineries which supply their starting materials. Next the monomer is polymerized to form polyvinyl chloride (PVC) resin, usually in solid form, and the bulk PVC resin is shipped to a large number of manufacturers who extrude, mold, roll, or otherwise form it into a variety of finished products.

PVC is easily made into films and sheets, electrical insulation, paper and textile coatings, phonograph records, and many other products. Because of its versatility it is the second most used polymer after polyethylene (Figure 1). In 1974, PVC plastics and copolymers accounted for approximately 1% of the U.S. gross national product. Major uses of PVC in the United States appear in Table I.

In the United States, about 700 000 workers fabricate products from PVC and about 6500 persons manufacture vinyl chloride and convert it to PVC, thus coming into direct contact with VCM (Table II).

The Problem

In January 1974 B. F. Goodrich Co. voluntarily revealed to federal and state regulatory officials that since 1971 three workers at its PVC polymerization plant in Louisville, Ky. had died of angiosarcoma of the liver. Because this form of cancer is extremely rare (usually no more than 25 cases are reported per year in the U.S.), this disclosure caused immediate alarm. B. F. Goodrich workers who were in contact with PVC only and not VCM were apparently unaffected, so the initial hypothesis was that vinyl chloride was the culprit.

A few weeks later, at the request of the

Chloride Story

U.S. Department of Health, Education and Welfare, Britain's Imperial Chemical Industries published the results of toxicological studies by Caesare Maltoni of the University of Bologna, Italy (2). In August 1972, Maltoni discovered in a test rat exposed to vinyl chloride a liver angiosarcoma later found to be essentially identical with those that had killed the PVC workers. In January 1973, a team of three scientists representing the U.S. chemical industry visited his laboratory to study his results. The data published in February 1974 are shown in Table III.

In the experiment, rats were exposed to vinyl chloride in air for four hours a day, five days a week, for 12 months. At all exposure levels above 50 parts per million (ppm), liver cancer was induced. No angiosarcomas were found in controls or in rats exposed similarly to 2500 ppm of vinyl acetate. These results were supplemented at a May 10 to 11, 1974 meeting of the New York Academy of Sciences and American Cancer Society where Maltoni reported the incidence of angiosarcoma in rats at an exposure level of 50 ppm in air. Several other types of tumors were also found.

By May 1974, a cause and effect relationship between vinyl chloride and human angiosarcoma was generally accepted. Confirmed cases of cancer in workers at PVC plants had risen to 19, 17 of whom were already dead.

Later, in the United States and nine other countries, a total of 32 cases were diagnosed. A recall of aerosol hair sprays using vinyl chloride as propellant was ordered by the Food and Drug Administration, and the Environmental Protection Agency (EPA) asked makers of 23 insecticide sprays to reformulate their products to eliminate vinyl chloride. The EPA order did not recall products



Tiny polyvinyl chloride cubes used in outdoor siding for homes

Carcinogenic—cancer-producing

Mutagenic—producing a significant and permanent change in the hereditary material

Teratogenic—producing monstrosities or malformations in the developing embryo

Molded polyvinyl chloride containers for lubricants, detergents, and edible oils



already packaged, and the names of many manufacturers were withheld because the presence of vinyl chloride in their products was deemed to be proprietary information. The Occupational Safety and Health Administration (OSHA) of the U.S. Department of Labor set a temporary standard of 50 ppm in air for plants manufacturing vinyl chloride and PVC as well as for PVC fabricating facilities. EPA set no standards for ambient air outside PVC plants because measurements indicated that the lowest detectable level (1 ppm) of vinyl chloride was rarely exceeded in these locations.

In October 1974, OSHA extended the interim level of 50 ppm to January 1, 1975, after which date a 1 ppm eight-hour average with a maximum of 5 ppm over any period longer than 15 minutes was to be required (5). If such standards could not be met, companies were required to provide workers with respiratory equipment. On December 14, 1974, the Second U.S. Circuit Court of Appeals ordered a stay of these rules until it could review them. In early February 1975, it found the rules "clear, definite and . . . entirely feasible" and ordered them put into effect by April 1. For the first year workers are required to wear respirators if the concentration of VCM exceeds 25 ppm, and respirators must be available at all times. After April 1, 1976, respirators will become mandatory whenever levels exceed the standards. The Society of the Plastics Industry has appealed this Circuit Court decision to the U.S. Supreme Court.

Detecting Chemical Carcinogens

More than 40 years elapsed between the introduction of vinyl chloride into commerce and the discovery of its cancer-causing ability. During this period production rose until nearly 100 000 tonnes of vinyl chloride were lost to the environment each year. Importance of vinyl chloride to the economy had become so great that when OSHA proposed a limit of 1 ppm, one industry spokesman claimed it would "throw two million jobs down the drain." Some observers claim that industry was aware of and withheld the results of Maltoni's study of carcinogenicity for some months, postponing regulation for as long as a year (3). But leaving this aside, why did detection of carcinogenic effects take so long?

Principal difficulty is the long latency period between exposure to a carcinogen and the development of a cancerous tumor. Average length of exposure to vinyl chloride of affected B. F. Goodrich workers was 19 years, a latency period which falls within the normal range of 15 to 40 years for cancer in humans. Although there is evidence that increasing the dose of a carcinogen increases the incidence of disease, chronic exposure is not necessary. Once an individual has received enough of the compound, whether in a single dose or extended over a period of years, cancer may develop. Moreover, there appears to be no threshold concentration below which carcinogenic effects do not occur, although the fraction of the population affected by disease decreases with reduced exposure.

As a result of the long latency period, establishing a cause and effect relationship between a chemical and cancer is difficult. Animals such as rats are often used to test for carcinogenesis. They have much shorter latency periods than humans, and the number of animals required for adequate statistics can be reduced if high dosages are used, but this introduces dual difficulties. Data must be extrapolated from high to low doses, and differences in the metabolism of test animals and humans introduce uncertainty in translating results from one species to another. A substance carcinogenic in rats may be metabolized to a harmless form by humans, and innocuous substances may be converted into carcinogens. It can be argued effectively that humans, because of their greater variety of cell types, may be more susceptible than test animals.

In view of the difficulties of discovering carcinogens, how did it happen that the effect of vinyl chloride on humans was detected at all? Answer is that the cancer induced by

Table I: Major Uses for PVC in the United States for 1964 (8)

Use	Million kg. of total	% of total
Building and construction	213	12
Gutters and downspouts, window sills, pipes and fittings, cladding and siding, waterstops	157	9
Flooring	157	9
Tiles, continuous flexible floor	157	9
Trig materials	184	10
Electrical	184	10
Wire and cable coverings, conduit	184	10
Clothing	73	4
Rainwear, shoes, baby pants	73	4
Home furnishings	221	12
Wall coverings, garden hose, curtains, upholstery	221	12
Packaging	94	5
Film, bottles, thermoformed containers	94	5
Toys and leisure	97	5
Photograph records, balls, dolls, golf bags	97	5
Transportation	102	6
Upholstery and seat covers, wire covering, crash pads	102	6
Miscellaneous	64	4
Tubing, credit cards, paints and lacquers	64	4
Total	1281	72

Table II: Producers of VCM in the United States (8)

Company	Location	Capacity, million kg./year
Allied Chemical Corp.	Galveston, Tex.	135
American Chemical	Watson, Calif.	79
Continental Oil Co.	Lake Charles, La.	77
Dow Chemical Co.	Freeport, Tex.	52
Eastman	Oyster Creek, Tex.	32
Diakone Sharnock	Plaquemine, Fla.	135
Eastman	Dodge Park, Tex.	45
Eastman	Baton Rouge, La.	135
Eastman	Houston, Tex.	31
Eastman	Culver City, Calif.	135
Eastman	Galveston, Tex.	135
Eastman	Lake Charles, La.	135
Eastman	Houston, Tex.	115
Total		1281

Table III: Incidence of Liver Cancer in Test Rats Exposed to Vinyl Chloride (2)

Exposure to vinyl	Rats with cancer	Rats examined
100%	49	69
50%	11	12
25%	7	7
12.5%	5	5
6.25%	4	4

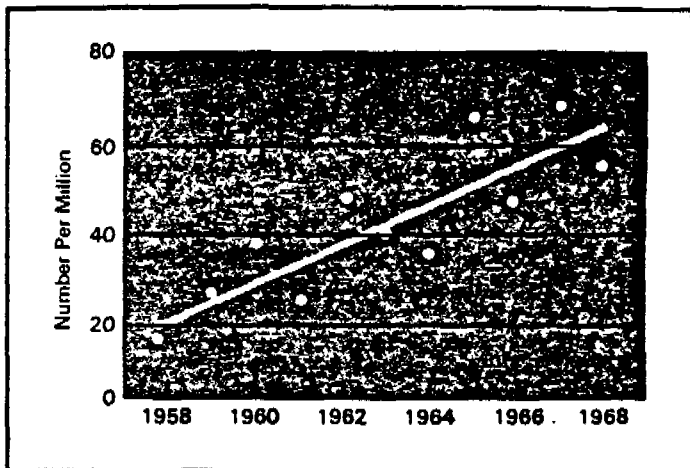


Figure 2. Incidence of cancer of the nervous system among Swedish children 0 to 4 years old

vinyl chloride is rare enough that even a single case is highly noticeable. Also workers in the PVC plant constituted a well-defined group with well-known exposure to vinyl chloride.

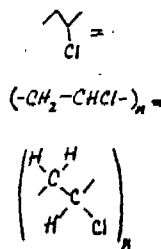
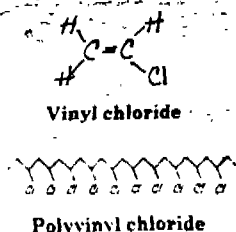
Other carcinogens may not produce such obvious effects. Indeed, evidence is that the greatest damage from vinyl chloride itself is not due to liver angiosarcoma but to the other, more common cancers it induces. Studies done at the Harvard School of Public Health indicate that lung cancers and brain cancers occur in vinyl chloride workers at rates 60% and 320% above the national average (4). Mutagenic effects have also been discovered now that angiosarcoma has focused attention on vinyl chloride. A substance which increased the incidence of prevalent cancers such as those of the lung or brain by only 10% and which was not confined to a workplace environment, would be almost impossible to detect. It has been suggested that a substance which reduced IQ by 10% but caused no overt symptoms would be completely unnoticed, despite its extremely deleterious effect on human society.

Incidence of cancer has increased a good deal during the 20th century and all of the increase cannot be attributed to better methods of diagnosis and the fact that other killer diseases have been brought under control. Even within a particular age group and among the young, cancer is on the rise as is shown by the data in Figure 2 for the 0- to 4-year age group in Sweden (1). During the decade 1958 to 1968, incidence of cancer of the nervous system increased threefold in this group.

No data are yet available to indicate unequivocally whether this increase is associated with increased levels of industrialization, but



Polyvinyl chloride is used extensively in wire and cable insulation



a number of disturbing studies have recently lent weight to this speculation. The National Cancer Institute (NCI) has tabulated deaths due to cancer between 1950 and 1970 in all counties of the United States. Those counties having high rates of cancer deaths correlate well with regions that were heavily industrialized prior to 1940. In view of the 15- to 40-year latency period between exposure to a carcinogen and development of cancer, this does not contradict the hypothesis that increased levels of air and water pollution might lead to increased incidence of malignant tumors.

In another study, EPA discovered a possible link between cancer and drinking water supplies (6). Both this and the NCI study indicate that a major problem may exist along the lower Mississippi River in Louisiana, an area with a high concentration of petrochemical plants. Known carcinogens have been discovered at low concentrations in the water supply. Some appear to have been released directly from chemical plants, but others are apparently synthesized by combination of industrial effluents with chlorine used to disinfect drinking water.

Because of such findings, many observers have pointed out that the few cases of angiosarcoma of the liver observed so far may be only the tip of an iceberg. With a 20-year latency period and the greatly increased numbers of workers exposed, the number of angiosarcomas may well continue to rise for the next two decades, even if all exposure is reduced to the 1-ppm level required by OSHA. Also, because of the increased incidence of carcinogens in the environment over the past few decades, other types of cancer may begin to appear. Cancers caused by vinyl chloride may well be an early warning of problems yet to come.

Testing for Carcinogens

With testing of carcinogenic and mutagenic compounds so time-consuming and expensive, how can we check all the compounds in-



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troduced into commerce? It seems likely that this will prove impossible, but also unnecessary. Many new chemicals, such as dyes used in food and paper or optical brighteners used in textiles, serve purely cosmetic functions, and little harm to society would be caused by halting production entirely. In other cases, such as that of vinyl chloride, the substance serves a very useful function, and its dangers must be balanced against its benefits before deciding whether to ban it. Here testing must be carried out and at the same time considerable effort made to find substitutes in case production of the material has to be stopped.

The Toxic Substances Control Act of 1973 represents a move toward adequate testing. It would require industry to test new chemicals and notify EPA before producing them in commercial quantities. Although different versions of this bill were passed by the U.S. Senate and House of Representatives in 1973, they became stalled in a House-Senate Conference Committee during the fall of 1974. New bills have been introduced in both legislative bodies this year. The Senate bill and a draft version produced by EPA both require that manufacturers submit test data on a new compound months before beginning commercial production. Compromises between the House and Senate may result in action later this year.

Others have suggested that better toxicological tests could be done with less economic disadvantage to small companies if government-supported and -operated regional testing laboratories, on the model of the Atomic Energy Commission National Laboratories, were established. These labs would provide greater expertise in this area than could be mustered by any but the largest corporations.

Whatever approach is taken it will come none too soon. The lesson of vinyl chloride has only begun to unfold, but is quite clear. Spread of synthetic chemicals whose toxic, teratogenic, mutagenic, and carcinogenic properties have not been thoroughly evaluated may have very serious consequences. Moreover, these effects often cannot be readily detected and once found may not be immediately reversible.

References

- (1) *Ambio*, June 1972, 88.
- (2) *Chem. Eng. News*, Feb. 25, 1974, 16.
- (3) *Ibid.*, May 20, 1974, 16; May 27, 1974, 5; June 10, 1974, 3, 12; July 8, 1974, 21, 37.
- (4) *Ibid.*, July 22, 1974, 9.
- (5) *Chemistry*, Nov. 1974, 27.
- (6) *Ibid.*, Feb. 1975, 16.
- (7) *Ibid.*, May 1975, 24.
- (8) "Encyclopedia of Polymer Science and Technology," 1971, Vol. 14, 452, Wiley-Interscience, New York, N.Y.