Human Exposures to Ethylene Dichloride

LOIS SWIRSKY GOLD
Department of Biochemistry
University of California
Berkeley, California 94720

Attempts to regulate human exposures to carcinogenic substances on a rational basis require valid and, where possible, quantitative information about the prevailing sources and levels of exposure. Such data need to be evaluated in conjunction with scientific judgments about the carcinogenic strength of a chemical, its other health effects, statistical estimates of the carcinogenic risk to humans, and the costs and benefits of various regulatory strategies.

This discussion aims at synthesizing and evaluating a large variety of estimates and measurements of human exposures to ethylene dichloride (EDC; 1,2-dichloroethane) and at improving the estimates wherever possible. From a methodological perspective it may be useful to think of EDC as one example of a whole range of chemicals that are potential carcinogens but have yet to be investigated in depth. Many of the data bases and government sources used here for EDC provide bits and pieces of important information about a large number of substances. In general, quantitative information about human exposures is difficult to obtain and estimates are subject to considerable uncertainty.

Three areas of exposure are discussed: production and consumption patterns, occupational exposures (where a relatively small subgroup of the total population potentially has relatively great exposure), and the much larger general population (which may be exposed to relatively lower levels in air, drinking water, food, and consumer products). The largest exposure to EDC is likely to be via inhalation, because of its volatility; however, absorption through the skin or through ingestion of drinking water and food can also occur.

Currently, federal regulation of exposures to EDC is based upon toxic effects other than carcinogenicity.

PRODUCTION AND CONSUMPTION PATTERNS

With an annual production of 11 billion pounds, EDC is the largest volume synthetic organic chemical manufactured in the United States. Worldwide capacity production is 51 billion pounds. This enormous volume is due primarily to demand for vinyl chloride (VC), for which EDC is a feedstock (Fig. 1).

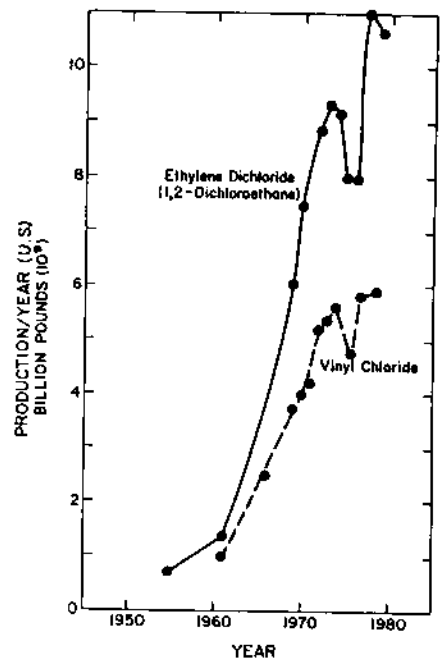

Figure 1
Production of EDC and VC. Data from *Chemical and Engineering News* (1960-1979.) Data for 1955 from SRI International (1979).

EDC was the first chlorinated hydrocarbon known and was initially produced in 1795 (Hardie 1964). Commercial production in the U.S. has been reported since 1922 (U.S. Tariff Commission 1923); however, rapid growth did not begin until the 1960s, with increases of about 10% per year. (The production decline in the mid-1970s was due to a general slowdown of the U.S. economy.) Projections for the next few years are for an annual growth rate of 5%.

Most EDC is used captively by the 11 companies that produce it in 17 plants. Only about 15% is sold on the open market, and the bulk of this amount is used by 10 additional plants for the manufacture of other chemicals (SRI International 1979). EDC production facilities are geographically clustered on the Gulf Coast; only two plants—one in Calvert, Kentucky, and one near Los Angeles—lie outside this region.

Ninety-eight percent of all EDC is used in the chemical industry for the production of VC, 1,1,1-trichloroethane, ethyleneamines, vinylidene chloride (VDC; 1,1-dichloroethene), perchloroethylene (PCE; tetrachloroethylene), and trichloroethylene (TCE). Much of the remainder (196 million pounds) is used as a lead scavenger in gasoline (Table 1). Miscellaneous uses of EDC (lb/yr) are pesticides (2 million); textile and equipment cleaning (3 million); extracting oil from seeds, processing animal fats, pharmaceuticals (2 million); production

Table 1
Estimated U.S. Consumption Pattern for EDC, 1977

	Pounds (10^6)	% Total consumption	Projected annual growth rate 1977–1982 (%)
VC	9,460	85	5 to 8
1,1,1-Trichloroethane	473	4	4 to 5
Ethyleneamines	299	2	−2 to −4
VDC	213	2	5 to 7
PCE	191	2	0 to 2
TCE	205	2	−2 to 3
Lead scavenger	196	2	−15
Miscellaneous	11	<1	–
Total	11,048	100	5 to 6

Adapted from data in *Chemical economics handbook,* SRI International (1979).

of polysulfide elastomers (1 million); and other uses (1 million) (SRI International 1979; E. Fry, pers. comm.).

An overview of the amount of EDC estimated to have been dispersed in commercial products and emitted during manufacture in 1977 is presented in Figure 2. EDC is not known to occur in nature (Johns 1976). The amount

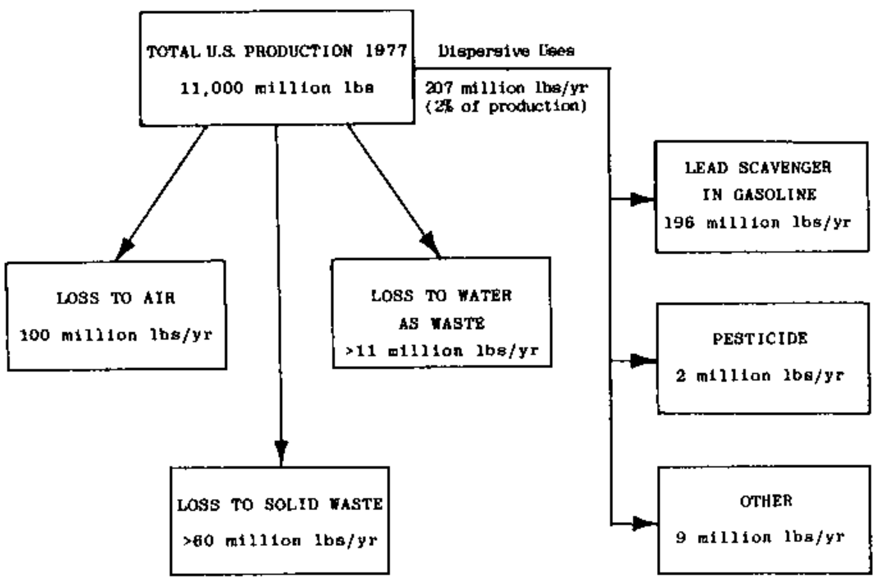

Figure 2
Estimated environmental release of EDC during 1977. Estimates are based upon information contained in Auerbach Associates (1978); Storm (1978); Drury and Hammons (1979); and SRI International (1979); E. Fry (pers. comm.); P. Williams (pers. comm.).

released is estimated to be more than 378 million pounds annually. Large amounts are emitted during the manufacture of EDC and its chemical end products: approximately 100 million pounds as air emissions, more than 11 million pounds in wastewater, and more than 60 million pounds in waste tar, which is primarily a remainder from the production of VC. An estimated 207 million pounds of EDC were dispersed in commercial products; of this, 196 million were used in leaded gasoline. Although relatively small in volume compared to total production, the 2 million pounds used in pesticides and the 9 million pounds present in other products may result in exposures of varying magnitude in many occupational and nonoccupational settings.

WORKER EXPOSURES

The most recent estimates from the National Occupational Hazard Survey 1972–1974 conducted by the National Institute for Occupational Safety and Health (NIOSH) indicate that between 60,000 and 1.6 million workers are potentially exposed to EDC (Table 2). (In 1977 NIOSH reported 1.9 million exposed; however since that time more complete information on product contents has reduced the estimate to 1.6 million [NIOSH 1977; NIOSH 1979b].) The lower estimate is based upon observed exposures to the chemical in its normal state or as an ingredient in a trade name product. The higher estimate is possible because it includes potential exposures to similar products, which NIOSH thinks might contain the chemical and whose contents have yet to be ascertained. A midrange estimate of 1.3 million is obtained by projections based on similar products for only those 34 industries where actual products containing EDC have already been identified (Table 2).

Although production data show that only a small proportion of all EDC is dispersed outside the chemical industry, these occupational estimates indicate that a large number of workers are potentially exposed across a broad spectrum of industrial classifications. Between 35,000 and 1.5 million workers outside of the chemical industry are estimated to be in occupations where EDC is used (Table 2). Further evidence for this widespread use is provided in Tables 3 and 4, which list the kinds of products identified as containing the chemical in 1972–1974 and the industries recently inspected by NIOSH and the Occupational Safety and Health Administration (OSHA) for exposures to EDC.

The current OSHA standard for employee exposure to EDC is 50 ppm (200 mg/m^3) as an 8-hour time-weighted average (TWA), with an acceptable ceiling concentration of 100 ppm for 5 minutes in any 3-hour period. Concentrations should never exceed 200 ppm (OSHA 1978). No data are available about the prevailing levels of exposure on a TWA basis; however, information from the OSHA Management Information System datafile indicates that of the 28 companies identified as having been inspected for EDC between 1972 and 1979, three had exposure levels exceeding the standards. In one chemical plant the ceiling or peak limit was exceeded; in a footwear plant and a plastic

Table 2
Estimates of Numbers of Workers Potentially Exposed to EDC, 1972-1974

Standard industrial classification	Estimate based on actual and trade name products[a]	Estimate based on similar as well as actual and trade name products[a]
Agriculture services and hunting	100	7,700
Oil and gas extraction	100	2,100
General building contractors	600	5,500
Heavy construction contractors	600	5,800
Ordnance and accessories	< 100	1,500
Food and kindred products	2,000	28,200
Tobacco manufactures	700	1,000
Apparel and other textile products	300	4,300
Lumber and wood products	< 100	3,700
Furniture and fixtures	100	11,000
Paper and allied products	700	30,400
Printing and publishing	100	100,700
Chemicals and allied products	25,400	74,100
Petroleum and coal products	200	8,000
Rubber and plastics products, NEC[b]	1,400	24,700
Leather and leather products	100	3,600
Stone, clay, and glass products	200	34,400
Primary metal industries	800	50,200
Fabricated metal products	800	52,200
Machinery, except electrical	3,200	101,000
Electrical equipment and supplies	1,700	60,000
Transportation equipment	1,000	56,200
Instruments and related products	400	21,000
Miscellaneous manufacturing industries	500	13,000
Local and interurban passenger transit	1,900	7,500
Trucking and warehousing	800	15,600
Transportation by air	1,000	38,700
Electric, gas, and sanitary services	100	17,400
Wholesale trade	2,200	114,900
Retail general merchandise	200	18,000
Automotive dealers and service stations	4,300	142,000
Personal services	1,600	12,300
Miscellaneous business services	< 100	27,900
Medical and other health services	8,000	177,100
Total	60,600	1,268,000
Total including 328,300 workers potentially exposed in 26 other industries		1,596,300

Data from National Occupational Hazard Survey Datafile (NIOSH 1979b).
[a] Numbers rounded to nearest hundred.
[b] Not elsewhere classified.

Table 3
Types of Products Containing EDC, Which Were Observed in the Workplace, 1972-1974

Acrylic cement	masking compound
Tack primer	pesticide
Solvent	automobile antiknock additive
Deletion fluid	seam sealer
Paint	carburetor and parts cleaner
Disinfectant	

Data from National Occupational Hazard Survey, Trade Name Products resolved for 1,2-dichloroethane as of December 1979 (NIOSH 1979b).

EDC was known to be an ingredient in these products in 1972-1974. Since that time, products may have been reformulated to remove the chemical, or the whole product may have been removed.

Table 4
Industries Inspected for Exposures to EDC

OSHA inspections, 1972-1979
- Chemical and chemical preparations[a]
- Rubber and plastic footwear[b]
- Miscellaneous plastic products[c]
- Macaroni and spaghetti
- Electrical compounds
- Shipbuilding and repair
- Miscellaneous manufacturing
- Bags, except textile
- Surgical and medical instruments
- Vinyl resins
- Commercial printing
- Refuse system
- Grain
- Oil field
- Aircraft parts
- Agricultural chemicals and pesticides

NIOSH inspections, 1973-1977
- Steel tool and engineering
- Grain elevators
- Police scientific laboratory

Data from OSHA Management Information System, 1977 and 1979 (OSHA 1979); NIOSH Health Hazard Evaluations Search (NIOSH 1979a).
[a] In one plant the acceptable ceiling or peak concentration was exceeded.
[b] In one plant the 50-ppm standard was exceeded by 1.1-2.0 times, according to the OSHA severity rating codes.
[c] In one plant the 50-ppm standard was exceeded by 2.1-3.0 times, according to the OSHA severity rating codes.

products plant the 50-ppm standard was exceeded. All 3 establishments were cited. Exposures in the other 25 companies and in the 3 companies inspected by NIOSH were all within the allowable limits (Table 4; NIOSH 1979a; OSHA 1979).

The current 50-ppm standard is based upon toxic effects other than cancer. In 1976 NIOSH recommended an exposure limit of 5 ppm on the basis of reports that workers chronically exposed to 10-15 ppm experienced nervous system and liver effects. Nursing mothers were also warned not to work with the chemical because a study indicated that it has been found in the milk of exposed women (NIOSH 1976). Following the positive National Cancer Institute (NCI) cancer bioassay, NIOSH recommended that EDC be handled as a carcinogen in the workplace and that the standard be revised downward to 1 ppm (NIOSH 1978a,b,c). These recomendations have not become government policy.

A detailed risk assessment on EDC is beyond the scope of this discussion, but it does seem that a reevaluation of the current OSHA standard is called for. Ideally, such an evaluation should include a more complete understanding of the apparently divergent results of the animal feeding and inhalation studies (Hooper et al., this volume).

From the NCI bioassay, our project on carcinogenic potency at the University of California at Berkeley, has estimated that for rats a daily dose of about 10 mg EDC/kg body weight for a lifetime will induce tumors in half of otherwise tumor-free animals. For mice the corresponding daily dose is about 70 mg/kg body weight (Ames et al., this volume; Hooper et al., this volume).

These estimates may be compared to the levels that workers currently are permitted to inhale. (The amount that workers actually do breathe in will vary considerably and may be much lower.) If a worker who weighed 70 kg breathed in 7 m^3 of air containing 50 ppm (200 mg/m^3) EDC daily, he would be exposed to 20 mg/kg each day. If we assume all of this is absorbed, the rate (kg body weight) is close to that which we estimate will induce tumors in 50% of rats and mice. The similarity of these levels suggests the wisdom of reevaluating the current threshold limit value on the basis of a detailed risk assessment.

Quantitative information on the actual levels to which workers are exposed is scarce; such data obviously would be useful in any evaluation of hazard from toxic substances. Currently the OSHA Management Information System reports the severity rating of inspections that exceed OSHA standards; it would be useful to report the levels monitored even when these are within the allowable limits. If future NIOSH occupational hazard surveys were to include data on the length of time or type of exposures workers in various occupations have to specific substances, this too would be an important source for regular use in assessing hazards of chemicals that are candidates for regulatory action.

LEADED GASOLINE

The largest dispersive use of EDC is as a lead scavenger in gasoline, for which 196 million pounds were consumed in 1977. This amount is expected to decline in the future as unleaded gasoline captures the fuel market; however, leaded gas will continue to fuel some trucks and older cars. In addition to gas station attendant and other worker exposures from this use, about 30 million Americans are exposed to EDC while filling their tanks in self-service gas stations. These exposures are estimated at 1.5 ppb (6 $\mu g/m^3$) for 2.2 hours per year—a TWA of only 0.0004 ppb (Suta 1979). Most EDC is destroyed in the engine during combustion. A small amount evaporates from gas tanks and from refueling; this results in exposures estimated at 0.01-0.03 ppb to about 14 million people who live near gas stations or in urban areas (Suta 1979).

FOOD-RELATED PRODUCTS

EDC is potentially available for human consumption if it is present as a residue in finished products from the following uses: solvent to extract spice oleoresins, pesticide, grain fumigant, solvent to clean grain-mill machinery, and adhesive coating in food packaging.

Federal regulations allow 30 ppm as a residue in spice oleoresins (U.S. Code of Federal Regulations). Actual residues have been found in 11 of the 17 common spices examined, at levels of 2-23 ppb (Page and Kennedy 1975). Since only small quantities of spices are consumed, ingestion from this source is not expected to be very large.

EDC is registered for agricultural use in a variety of formulations and is used commercially for postharvest fumigation, bark treatment, soil fumigation, and spraying of agricultural premises. In 1977, 84 such pesticide products were registered with EPA by 52 different companies; together they contained 2,190,261 pounds of EDC (E. Fry, pers. comm.). A list of these products is presented in Table 5 (pages 218-219) along with the concentration of EDC in each one (Drury and Hammons 1979; EPA 1979a).

Since 1956 EDC has been exempted from the requirement of a tolerance for residues when used as a postharvest fumigant on barley, corn, oats, popcorn, rice, rye, wheat, and sorghum. This exemption was based on baking tests, which showed no residues in bread cooked from fumigated flour; sensitivity of the method was 2 ppm (Monro 1969). More recently bread residues were measured usually below 0.05 ppm (Wit et al. 1969). Another recent study was unable to find residues in fumigated cereal samples and concluded that further research was needed to explain this result. The author noted that it was possible that either the EDC was only partially sorbed by the wheat because of rapid volatilization or the EDC was changed to a non-EDC residue (Berck 1974).

In 1971 the Joint Meeting of the FAO Working Party of Experts and the WHO Expert Committee on Pesticide residues evaluated EDC. It was noted that little information was available on residues in food reaching the consumer, and guidelines were suggested for residue limits of 10 ppm in milled cereal products and 0.1 ppm in cooked cereal products and bread (WHO 1972). Since these guidelines were suggested, the NCI bioassay has been done and more sensitive methods to detect residues have become available.

It seems advisable to review the policy of an exemption from a tolerance for fumigated grains. As a grain fumigant, EDC is commonly mixed with carbon tetrachloride to reduce flammability. It is often combined with ethylene dibromide (EDB; 1,2-dibromoethane) which is a considerably more potent carcinogen than EDC. Both EDB and carbon tetrachloride are on the RPAR list of EPA. Thus, subsitution by some other less toxic fumigant would be desirable.

Pesticide residues may also result from spraying home-grown fruits and vegetables. Currently, the consumer can purchase EDC in pesticides for home garden use to control tree borers and as a solution for a general insecticide. In northern California it is possible to purchase a product containing EDC that is recommended as a diluted spray for food crops like strawberries and cabbage within 1 day of harvest. These foods are eaten raw and hence any residues would not be removed by cooking.

CONSUMER PRODUCTS

A 1979 industry profile prepared for the Consumer Product Safety Commission reports that consumer products do not contain significant amounts of EDC (Winslow and Barr 1979). Manufacturers of some products that once contained EDC—certain fumigants and some solvent cements for acrylic plastics—have voluntarily removed EDC from their products following the positive NCI bioassay. Fur and garment fumigants containing the chemical are not sold as consumer products.

Although the industry profile reports that California is considering legislation to ban the use of EDC in home-use pesticides, I could not confirm this legislation from state agencies.

Since industrial products that were observed to contain EDC in the NIOSH Occupational Hazard Survey might also be consumer products, the product names from the list in Table 3 were sent to the Consumer Product Safety Commission. A hazard evaluation by the Commission has just determined that only one product is currently sold to consumers; this is a cleaning solvent containing 50 ppm EDC (P. Preuss, pers. comm.). The fact that EDC has been found in domestic sewage (Versar, Inc. 1975) suggests that it may be or has been used in consumer products.

Table 5
Pesticide Products Containing EDC, 1977

Product name	% EDC	Product name	% EDC
Big F "LGF" Liquid Gas Fumigant	75.0	914 Weevil Killer and Grain Conditioner	63.1[a]
Farmrite Mushroom Spray	75.0	Cooke Kill-Bore	50.0
Grain Fumigant	75.0	Destruxol Borer-Sol	50.0
Hydrochlor GF Liquid Gas Fumigant	75.0	Ferti-Lome Tree Borer Killer	50.0
Parson Lethogas Fumigant	73.5[a]	Hacienda Borer Solution	50.0
Best 4 Servis Brand 75-25 Standard Fumigant	70.3	Navlet's Borer Solution	50.0
Bug Devil Fumigant	70.3	Staffel's Boraway	50.0
Fumisol[b]	70.3	Chemform Brand Bore-Kill	35.0
Gas-O-Cide	70.3	Okay Mole and Gopher Fumigant	30.0
Riverdale Fumigant	70.3	Tri-X Garment Fumigant	30.0[a]
Standard 75-25 Fumigant	70.3	Brayton EB-5 Grain Fumigant	29.2[a]
Brayton Flour Equipment Fumigant for Bakeries	70.2	De-Pester Weevil Kill	29.2[a]
Brayton 75-25 Grain Fumigant	70.2	Formula 635 (FC-2) Grain Fumigant	29.2[a]
Cardinalfume	70.2	Grainfume MB	29.2[a]
De-Pester Fumigant No. 1	70.2	T-H Vault Fumigant	29.2[a]
Diamond 75-25 Grain Fumigant	70.2	Volcan Formula 635 (FC-2) Grain Fumigant	29.2[a]
Hill's Hilcofume 75	70.2	Dowfume EB-5 Effective Grain Fumigant	29.0[a]
Maxkill 75-25	70.2	T&C Fruit & Vegetable Insecticide and Miticide	28.0
Spray-Trol Brand Insecticide Fumi-Trol	70.2	Infuco 50-50 Spot Fumigant	26.84[a]
Stephenson Chemicals Stored Grain Fumigant	70.2	Selig's Selcofume	25.0
Vulcan Formula 72 Grain Fumigant	70.2	Cooke Bug Shot Law Special Spray Concentrate	20.0

Westofume Fumigant	70.2	Dowfume EB-15 Inhibited	20.0[a]
Zep-O-Fume Grain Mill Fumigant	70.2	J-Fume-20	20.0[a]
Diweevil	70.0	Max Spot Kill Machinery Fumigant	20.0[a]
Dowfume 75	70.0	Crest 15 Grain Fumigant	19.6[a]
Excelcide Excelfume	70.0	(FC-13) Mill Machinery Fumigant[b]	19.6[a]
Fume-O-Death Gas No. 3	70.0	Solig's Grain Fumigant No. 15	19.6[a]
Hydrochlor Fumigant	70.0	Spot Fumigant	19.6[a]
Infuco Fumigant 75	70.0	Dyna Fume	12.0[a]
J-Fume-75	70.0	Iso-Fume	11.4[a]
Pearson's Funigrain P-75	67.49	49'er Gold Strike Bonanza Plant Spray	10.25
Coop New Activate Weevil Killer Fumigant	66.0[a]	KLX	10.25
Pioneer Brand Grain Fumigant	66.0[a]	Agway Serafume	10.0[a]
Dowfume F	65.0[a]	Formula MU-39	10.0
FC-7 Grain Fumigant	64.7[a]	Max Kill Spot-59 Spot Fumigant for Mills and Milling Machinery	10.0[a]
De-Pester Grain Conditioner and Weevil Killer	64.6[a]	Serfume	10.0[a]
(FC-4) SX Grain Storage Fumigant	64.6[a]	Dowfume EB-59	9.0[a]
Selig's Grain Storage Fumigant	64.6[a]	Waco-50	9.0[a]
Sure Death Brand Millfume No. 2	64.6[a]	Leitte Spotfume 60	8.5[a]
Patterson's Weevil Killer	63.1[a]	Koppersol	3.0
T-H Grain Fumigant No. 7 Weevil Killer and Grain Conditioner	63.1[a]	Sirotta's Sircofume Liquid Fumigating Gas	1.0

Data from Office of Pesticide Programs, Product Label File, 1979 (EPA 1979a).
[a] Also contains EDB.
[b] This name is registered twice. It is produced by two different companies.

SOLID AND LIQUID WASTES FROM MANUFACTURING PLANTS

The environmental fate of waste products from the EDC-VC industry is of concern because of the large and still increasing production volume and because the waste tars are mutagenic (Jensen et al. 1975; Rannug and Ramel 1977). Information about waste disposal practices and their polluting potential is scarce.

In California, waste water and waste tar from EDC-VC production is disposed of in drums into Class-1 landfill sites; waste disposal manifests reported to the Department of Health Services indicate the composition of these wastes (California Administrative Code; Storm 1978). On the basis of a survey of these manifests, it is estimated that 9.6 million pounds of waste tar containing 25–75% EDC were disposed of in California in 1979 from one plant. Another 2 million gallons of wastewater containing 2% EDC, or about 400,000 pounds, were also buried (California Department of Health Services 1979). (The survey of hazardous waste manifests did not identify the producer or the Class-1 disposal sites.) Because waste volume and composition vary with production processes, it is difficult to assess total national volume. Projections from these California data to the U.S. give estimates of about 11 million pounds annually as EDC waste in water and 60 million pounds of EDC in more than 230 million pounds of waste tar from production of EDC and VC.

Outside California, some waste tar is disposed of by incineration; some is buried in disposal sites and recent air sampling of a landfill site in New Jersey detected EDC in amounts ranging from trace levels to a high of 14 ppb (57 $\mu g/m^3$) at a point 200 yards downwind of the dump (Pelizzari 1979). In 1975, one report indicated that wastes were disposed of as effluent to a river (Brown et al. 1975). In Europe, where large quantities of EDC tar were at one time dumped into the North Sea, waste disposal is now by incineration at sea.

In view of the large volume of waste and its hazardous composition, it would seem advisable to address several aspects of the disposal issue. What are the by-products of incineration and how much is removed? Would incineration be an economically feasible disposal method nationally? To what extent does EDC evaporate from disposal sites? Does EDC from landfills contaminate surface, ground, or drinking waters? Is waste tar or waste water currently being dumped into any river waters? What is the toxicity and fate of the large variety of chlorinated by-products in the EDC tar?

OCCURRENCE IN WATER

Chronic low-dose exposures to people may result from occurrence of EDC in drinking water, in the ppb range. Although these amounts are relatively small, there has been concern for health effects because of a lack of information about synergistic interactions and alterations of metabolic pathways that may result from chronic ingestion.

The National Organics Reconnaissance Survey (NORS) in 1975 reported EDC in the drinking water supplies of 26 of the 80 cities studied, at levels of 0–6 μg/liter (Symons et al. 1975). In a study of surface waters near heavily industrialized sites across the U.S., concentrations at usual levels of 1–2 ppb were found in 53 of 204 samples. Some concentrations were considerably higher, however, and one sample from the Delaware River Basin contained 90 ppb (Ewing et al. 1977). Other water monitoring has detected EDC in river waters in Europe at 0.7 μg/liter (Eurocop-cost 1976) and in tap water in Japan at 0.9 μg/liter (Fujii 1977).

The Office of Drinking Water at EPA has not yet proposed regulation of EDC but may do so under the Safe Drinking Water Act. The Office of Water Planning and Standards of EPA has drafted a proposal on ambient water quality criteria for chlorinated ethanes, including EDC. That office is considering an interim target risk level in the range of 1 in 100,000 to 1 in 10 million. Their calculations, based on the NCI data for mammary adenocarcinomas in female rats and using a one-hit model and a low bioaccumulation factor, indicate that a concentration of EDC in water to keep the cancer risk below 1 in 100,000 is 7 μg/liter. This calculation assumes consumption of 2 liters of water daily and a small amount of contaminated fish (EPA 1979b). A 70-kg person who consumed 2 liters of water every day containing 7 ppb (7 μg/liter) EDC, would be getting 0.2 μg (0.0002 mg)/kg body weight each day.

Whether or not EDC is produced as a result of the chlorination process is under discussion at EPA. Charcoal filtration is known to be 90–100% effective in eliminating EDC from drinking water.

EMISSIONS TO AIR

Attempts to measure EDC in atmospheric air have not detected it even in the ppb and ppt ranges (Grimsrud and Rasmussen 1975; Singh et al. 1977). Estimates of the half-life of EDC in the atmosphere range from weeks to months (Pearson and McConnell 1975). Exposures do result, however, for those people who live near EDC production plants. A recent EPA study monitored ambient air near production plants (PEDCo Environmental, Inc. 1979), and the data were subsequently used to estimate average exposures to the local populations. In the monitoring study, ambient EDC levels varied considerably and depended on such factors as plant production process and rate, emission control technologies used by the manufacturer, meteorological conditions, characteristics of the EDC point sources such as stack height, and location of the monitoring sites (Drury and Hammons 1979).

Dispersion modeling based on the living patterns of the nearby populations provides an estimate that 12.5 million people are exposed to average annual EDC concentations of 0.01–10 ppb (Suta 1979; Kellam and Dusetzina, this volume; Table 6). A 70-kg person breathing in daily 20 m^3 of air containing 10 ppb (40 $\mu g/m^3$) EDC would be getting an exposure of 11 μg (0.011 mg)/kg body weight each day. It is worth pointing out that an equivalent ppb in water would result in exposures about 40 times smaller: 10 ppb in water is 10 μg/liter and a 70-kg person drinks about 2 liters a day. This would result in an exposure of 0.3 μg (0.0003 mg)/kg body weight each day.

Table 6
Estimated Human Population Exposures to Atmospheric EDC Emitted by Producers

Annual average atmospheric EDC concentration (ppb)	Number of people exposed
10.0	1,700
6.00-10.00	3,300
3.00- 5.99	28,000
1.00- 2.99	280,000
0.60- 0.99	400,000
0.30- 0.59	1,500,000
0.10- 0.29	4,300,000
0.060-0.099	1,900,000[a]
0.030-0.059	3,500,000[a]
0.010-0.029	550,000[a]
Total	12,500,000

Data from Suta (1979).
[a] These are underestimates because the dispersion modeling results were not extrapolated beyond 30 km from each EDC production facility.

Most manufacturing losses of EDC to the environment occur as air emissions. The amount released is about half as large when EDC is produced by direct chlorination of ethylene than by the oxychlorination method. Currently, nearly 50% of all U.S. production is accomplished by the oxychlorination method (Drury and Hammons 1979). Some EDC is also released from manufacturing plants as a result of storage and distribution of the chemical.

Current control mechanisms for these emissions include scrubbers and condensers. Condensers are far more effective than scrubbers but have substantially higher capital and operating costs (Pervier et al. 1974). Control technologies also are available for emissions from storage tanks, and these are reportedly under study by several manufacturers (Schwartz et al. 1974).

EPA is currently considering regulation of EDC as an air pollutant and is in the process of assessing the risk to humans based on the NCI cancer bioassay.

ACKNOWLEDGMENTS

I am indebted to B. N. Ames and K. Hooper for helpful criticisms and to Elizabeth Higgins for bibliographical assistance. This work was supported by Department of Energy contract EY76-S-03-0034 PA156, by a California Policy Seminar grant to B. N. A., and by National Institute of Environmental Health Sciences Center grant ES-01896.

REFERENCES

Auerbach Associates, Inc. 1978. *Miscellaneous and small volume consumption of ethylene dichloride. EPA-68-01-3899 and AAI-2431-104-TN-1. EPA.* Auerbach Associates, Inc., Philadelphia, Pennsylvania.

Berck, B. 1974. Fumigant residues of carbon tetrachloride, ethylene dichloride, and ethylene dibromide in wheat, flour, bran, middlings, and bread. *J. Agric. Food Chem.* 22:977.

Brown, S. L., S. Y. Chan, J. L. Jones, D. H. Liu, K. E. McCaleb, T. Mill, K. N. Sapios, and D. E. Schendel. 1975. *Research program on hazard priority ranking of manufactured chemicals. Phase II. Final Report to the National Science Foundation.* SRI International, Menlo Park, California.

California Administrative Code. Title 22, Division 4. Chapter 30: Minimum standards for management of hazardous and extremely hazardous wastes. California Department of Health Services.

California Department of Health Services. 1979. Source of survey of waste disposal manifests: Paul Williams

Chemical and Engineering News. 1950-1979. "Top-Fifty Chemical Products."

Drury, J. S. and A. S. Hammons. 1979. *Investigations of selected environmental pollutants: 1,2-Dichloroethane.* EPA 560/2-78-006. EPA Oak Ridge National Laboratory, Oak Ridge, Tennessee.

EPA (Environmental Protection Agency). 1979a. Office of Pesticide Programs. Product Label File Printout from Information on Microfiche, 3rd Edition, July 1978.

———. 1979b. "Chlorinated Ethanes. Ambient Water Quality Criteria." Draft, Criteria and Standards Division, Office of Water Planning and Standards. EPA. Washington, D.C.

Eurocop-cost. 1976. *A comprehensive list of polluting substances which have been identified in various fresh waters, effluent-discharges, aquatic animals, and plants, and bottom sediments,* 2nd ed., p. 41. EUCO/MDU/73/76, Commission of the European Communities. Compiled by Water Research Center (Stevenage Laboratory) Stevenage, Hertfordshire, England.

Ewing, B. B., E. S. K. Chian, J. C. Cook, C. A. Evaris, P. K. Hopke, and E. G. Perkins. 1977. Monitoring to detect previously unrecognized pollutants in surface waters. EPA 560/6-77-015, p. 63-64, 73.

Fujii, T. 1977. Direct aqueous injection gas chromatography-mass spectrometry for analysis of organohalides in water at concentrations below the parts per billion level. *J. Chromatogr.* 139:297.

Grimsrud, E. P. and R. A. Rasmussen. 1975. Survey and analysis of halocarbons in the atmosphere by gas chromatography-mass spectrometry. *Atmos. Environ.* 9:1014.

Hardie, D. W. F. 1964. Vinyl chloride. In *Kirk-Othmer encyclopedia of chemical technology*, 2nd ed., vol. 5, p. 171. John Wiley & Sons, Inc., New York.

Jensen, S., R. Lange, G. Berge, K. H. Palmork, and L. Renberg. 1975. On the chemistry of EDC-tar and its biological significance in the sea. *Proc. R. Soc. Lond. B Biol. Sci.* 189:333

Johns, R. 1976. *Air pollution assessment of ethylene dichloride.* MTR 7164. The Mitre Corporation, McLean, Virginia.

Monro, H. A. U., ed. 1969. Manual of fumigation for insect control. *FAO Agric. Stud.* 79.

NIOSH (National Institute for Occupational Safety and Health). 1976. *Criteria for a recommended standard ... occupational exposure to ethylene dichloride (1,2-dichloroethane).* DHEW (NIOSH) publication number 76-139. Government Printing Office, Washington, D.C.

———. 1977. *National Occupational Hazard Survey.* Vol. 3. *Survey analysis and supplemental tables.* DHEW, NIOSH Division of Surveillance, Hazard Evaluations and Field Studies. Cincinnati, Ohio.

———. 1978a. *Revised recommended standard ... occupational exposure to ethylene dichloride (1,2-dichloroethane).* DHEW (NIOSH) publication number 78-211. Government Printing Office, Washington, D.C.

———. 1978b. Ethylene dichloride. *Current Intelligence Bulletin,* No. 25. DHEW.

———. 1978c. Chloroethanes: Review of toxicity. *Current Intelligence Bulletin,* No. 27. DHEW.

———. 1979a. Health Hazard Evaluations Search, as of December 1979.

———. 1979b. National Occupational Hazard Survey Data File as of December 1979. Source of printout: Joseph A. Seta.

OSHA (Occupational Safety and Health Administration). 1978. *General industry: OSHA safety and health standards.* OSHA 2206. Revised November 7, 1978.

———. 1979. Management Information System Datafile 1977 and 1979. Source of Data Analysis: William Cloe.

Page, B. D. and B. P. C. Kennedy. 1975. Determination of methylene chloride, ethylene dichloride, and trichloroethylene as solvent residues in spice oleoresins, using vacuum distillation and electron-capture gas chromatography. *J. Assoc. Offic. Anal. Chem.* 58:1062.

Pearson, C. and G. McConnell. 1975. Chlorinated C_1 and C_2 hydrocarbons in the marine environment. *Proc. R. Soc. London B Biol. Ser.* 189:305.

PEDCo Environmental, Inc. 1979. *Monitoring of ambient levels of ethylene dichloride (EDC) in the vicinity of EDC production and user facilities.* EPA 600/4-79-029. EPA, Research Triangle Park, North Carolina.

Pelizzari, E. D. 1979. *Ambient air carcinogenic vapors: Improved sampling and analytic techniques and field studies.* EPA 600-2-79-081. EPA, Research Triangle Park, North Carolina.

Pervier, J. W., R. C. Barley, D. E. Field, B. M. Friedman, R. B. Morris, and W. A. Schwartz. 1974. *Survey reports on atmospheric emissions from the petrochemical industry,* vol. 2. EPA-450/3-73-005-b. EPA, Research Triangle Park, North Carolina.

Rannug, U. and C. Ramel. 1977. Mutagenicity of waste products from vinyl chloride industries. *J. Toxicol. Environ. Health* 2:1019.

Schwartz, W. A., F. G. Higgins, Jr., J. A. Lee, R. Newirth, and J. W. Pervier. 1974. *Engineering and cost study of air pollution control for the petrochemical industry,* vol. 3. *Ethylene dichloride manufacture by oxychlorination.* EPA-450/3-73-006-c. EPA, Research Triangle Park, North Carolina.

Singh, H. B., L. J. Salas, and L. A. Cavanagh. 1977. Distribution, sources and sinks of atmospheric halogenated compounds. *J. Air Pollut. Control Assoc.* 27:332

SRI International. 1979. *Chemical economics handbook*. Menlo Park, California.

Storm, D. 1978. *Handbook of industrial waste compositions in California*. California Department of Health Services, Hazardous Materials Management Section. Berkeley, California.

Suta, B. 1979. *Assessment of human exposures to atmospheric ethylene dichloride*. Final Report to EPA Office of Air Quality Planning and Standards. SRI International, Menlo Park, California.

Symons, J. M., T. A. Bellar, J. K. Carswell, J. DeMarco, K. L. Kropp, G. G. Robeck, D. R. Seeger, C. J. Slocum, B. L. Smith, and A. A. Stevens. 1975. National organics reconnaissance survey for halogenated organics. *J. Am. Water Works Assoc.* 67:634.

U.S. *U.S. Code of Federal Regulations*. Title 21, Sections 172, 173, 175.

U.S. Tariff Commission. 1923. Census of dyes and other synthetic organic chemicals 1922. *Tariff Information Series*, no. 31. Washington, D.C.

Versar, Inc. 1975. *Identification of organic compounds in effluents from industrial sources*. Final Report to EPA Office of Toxic Substances, Washington, D.C. EPA 560/3-75-002.

Winslow, R. A. and H. W. Barr, Jr. 1979. *Final report on 1,2-dichloroethane in consumer products*. U.S. Consumer Product Safety Commission. Battelle, Columbus, Ohio.

Wit, S. L., A. F. H. Besemer, H. A. Das, W. Goedkoop, F. E. Loosjes, and E. R. Meppelink. 1969. *Results of an investigation on the regression of three fumigants (carbon tetrachloride, ethylene dibromide and ethylene dichloride) in wheats during processing to bread*. Report No. 36/69. National Institute of Public Health, Bilthoven, Netherlands.

WHO (World Health Organization). 1972. 1971 Evaluations of some pesticide residues in food. In *World Health Organization, Pesticide Residues Report No. 2*, p. 276. Geneva, Switzerland.

Banbury Report

5

ETHYLENE DICHLORIDE: A Potential Health Risk?

Edited by
BRUCE AMES
University of California
PETER INFANTE
OSHA
RICHARD REITZ
Dow Chemical Company

COLD SPRING HARBOR LABORATORY
1980