TOX
FILE
EDC

1

Vulcan Materials Company

CHEMICALS DIVISION / P. O. BOX 12283 • WICHITA, KANSAS 67277 • TELEPHONE 316 524-4211

THOMAS A. ROBINSON, Ph. D
DIRECTOR
ENVIRONMENTAL AFFAIRS

January 22, 1979

DOCKET OFFICER
DATE 1/29/79
TIME

Docket Officer
Docket No. H-079, Room S-6212
U.S. Department of Labor, OSHA
Third Street and Constitution Avenue, N.W.
Washington, D.C. 10210

Dear Sir:

Vulcan Materials Company, Chemicals Division, is a producer of 1,2-dichloroethane (ethylene dichloride) and as such wishes to submit comment on the OSHA request for information on 1,2-dichloroethane as published in 43 FR 56910, December 5, 1978.

Under the auspices of the Manufacturing Chemists Association, Vulcan is participating in an in-depth, inhalation toxicology study of the effects of ethylene dichloride (EDC)on rats and mice. Inhalation was chosen as the route of exposure since it represents the route of exposure most likely to be encountered in the workplace. The total toxicological study consists of five segments. An 18-month exposure bioassay study was conducted to evaluate effects of the chronic exposure to EDC and was supported by a concurrent clinical chemistry study of the long-term effects of EDC on various biological parameters. These studies were conducted by Dr. Cesare Maltoni, Bologna Tumour Institute and by Dr. F. Spreafico, Mario Negri Institute, respectively, and the final reports of these studies are expected to be ready shortly. In addition, studies are in progress on the effects of EDC on metabolism, teratogenicity and reproduction. The teratogenicity study is basically complete and the final report will be forthcoming in the near future. The reproduction study will be completed later this year.

In an interim final report on the 18-month bioassay study, Maltoni stated that "no 'specific' type of tumour has been found in treated animals (rats and mice)." Maltoni further stated, "No relevant changes in the incidence of tumours, normally occurring in the bred (sic) of mice used, has been observed." With respect to the rat study, he stated, "No relevant changes in the incidence of tumours normally occurring in this bred (sic) of rats used has been observed, following the treatment, apart from a moderate overall increase of benign mammary tumours (fibromas and fibroadenomas) in treated rats when compared to

controls, however, without a dose-response relationship, within the exposed groups. This phenomenum has been observed in correlated long-term bioassays of other compounds in the same animals, suggesting a possible role of stress."

Maltoni concluded with the statement, "On the basis of present data, it may be stated that in our experimental conditions DCE has failed to show specific carcinogenic potentialities," and "The presented data may be considered almost conclusive."

NIOSH Revised Criteria Document

In our review of the NIOSH Revised Criteria Document on EDC,[1] we noted that the document does cite the long-term bioassay study of Maltoni, but we believ that in essence NIOSH inappropriately disregards the study and did not give it the consideration which it merits. For example, the document focuses on the marginal increase of benign mammary tumors in the Sprague-Dawley rat, (a strain with a known propensity for the spontaneous development of mammary tumors) and appears to place more emphasis on this occurrence than it does on the general findings of the study. It should be noted that the incidence of mammary tumors in separate controls of 39/90 is not of significant difference from the 46/90, 41/90, 29/90, and 40/90 observed in animals exposed to 150, 50, 10, and 5 parts per million EDC, respectively.

The document continues in stating that "[w]hile increases in tumor incidences were not significantly different from controls at this level, increased incidences did occur, and higher levels of exposure may result in still greater incidences of tumors." The document fails to mention that initially the highest exposure level was greater than 150 ppm but was reduced, due to signs of severe acute toxicity. A higher exposure level than 150 ppm might have yielded no meaningful study at all, due to this observed effect.

The NIOSH document indicates that there is no epidemiological evidence to associate EDC with human cancers and writes off the existing seven epidemiological studies relative to the human exposure to EDC as referring only to physiological alterations and morbidity. We submit that if EDC is a potential human carcinogen of any significance, the incidence of such cancers would most likely have shown up in at least one of these studies.

---

[1] Occupational Exposure to Ethylene Dichloride - Revised Recommended Standard, NIOSH, September, 1978.

In addition, the document refers to the skin painting study by Dr. B. M. Goldschmitt of the Institute of Environmental Medicine, New York University. This study showed no increased incidence of tumors following application of EDC to the skin of mice. Further testing of EDC as an initiating agent for the tumor-promoter phorbol myristate acetate "for more than one year, (the combined treatment) yielded one animal (in 30) with one papilloma." A papilloma is a benign tumor of the epithelium, similar to a wart, and may have a virus as a causitive agent. Again, the NIOSH document discounts this negative finding in stating, "This study was not originally intended to test the carcinogenicity of ethylene dichloride per se when applied to skin. Greater numbers of experimental animals and greater quantities of ethylene dichloride applied to the skin would be necessary before any definitive conclusion could be made. NIOSH therefore considers the carcinogenic potential of ethylene dichloride via the dermal route to be undetermined at this time."

NIOSH, in the revised criteria document, than places great emphasis on th findings of positive mutagenicity in Salmonella typhinurium bacteria with the inconsistent statement that "[w]hile the relation of mutagenisis to carcinogenicity is not firmly established, the consistent, positive mutagenicity findings support a conclusion that ethylene dichloride be considered a carcinogen." (Emphasis added). Please note that they do not say a "potential carcinogen" but a "carcinogen."

From the general tenor of the criteria document, we get the distinct impression that selective interpretation of the studies cited above was used to yield only that information which would support the document's recommended exposure limitations and workplace standards. Although we do not challenge the findings of the NCI, where the route of exposure to EDC was via gastric intubation, we submit that this route of exposure is not typical of that encountered in the workplace and the high dose of EDC used in this study would correspond to a daily dose of about 7 grams for an individual weighing 150 pounds.

NIOSH Recommended Exposure Limitations and Work Practices

Having reviewed the NIOSH revised criteria document, we believe that the recommended permissible exposure limits of 1 ppm time-weighted average, for a 10-hour workday, 40-hour workweek, and the recommended ceiling concentration of 2 ppm, as determined over a 15-minute sampling period, are presently unjustified and not substantiated by any existing evidence that EDC is a significant potential human carcinogen. Our belief is supported by the fact that these PEL limitations are more restrictive than those currently

in effect for vinyl chloride and acrylonitrile, chemicals which have been associated with human cancers. In addition, we find that the workplace standards, regarding personal protective equipment and clothing, regulated areas, decontamination of equipment, mandatory showers, and the provision of clean work clothing on a daily basis, are more restrictive than the current standards for vinyl chloride and acrylonitrile. Therefore, based on the negative findings in the epidemiological studies and the negative results of the two separate animal studies (Maltoni and Goldschmitt), we believe that the recommendations contained in the criteria document are not warranted and have not been justified.

Emergency Temporary Standard

We believe that the preponderance of evidence presently available, relative to the routes of exposure most likely to be encountered in the workplace, indicates that an ETS is not necessary.

Recommendation

We recommend that the results of the toxicological studies currently in progress be considered in the evaluation of the necessity of imposing a more stringent standard for the occupational exposure to EDC. Since these studies will be completed in the near future, we believe that a delay by OSHA, on further action to modify or issue an occupational standard specific to EDC, is justifiable and warranted.

Sincerely yours,

Thomas A. Robinson

TAR:bl

2

United States Department of the Interior

BUREAU OF RECLAMATION
ENGINEERING AND RESEARCH CENTER
P.O. BOX 25007
BUILDING 67, DENVER FEDERAL CENTER
DENVER, COLORADO 80225

IN REPLY
REFER TO: D-203

JAN 18 1979

106.

DOCKET OFFICER
DATE 1/25/79
TIME

Docket Officer
Docket No. H-079, Room S6212
U.S. Department of Labor, OSHA
Third Street and Constitution Avenue, NW
Washington DC 20210

Subject: Review of Request for Comments and Information on Occupational Exposure to 1, 2-Dichloroethane (ER 78/1189)

Sir:

We have no special expertise concerning toxicological, metabolic, hereditary, carcinogenic, and other epidemiological studies related to occupational exposure to 1, 2-Dichloroethane. The current threshold limit value (TLV) for this material is not proposed to be changed, and Reclamation has adopted the limits as established by the American Conference of Governmental Industrial Hygienists.

Other than the utilization of this material in limited laboratory quantities for the analysis of paints and polymer concrete, this request and proposed standard would have no effect on the operations or mission of the Bureau of Reclamation.

Very truly yours,

John C. Peters
for

John C. Peters
Environmental Specialist

SL 080814

3

ETHYL CORPORATION
TOXICOLOGY AND INDUSTRIAL HYGIENE DEPARTMENT
ETHYL TOWER, 451 FLORIDA
BATON ROUGE, LOUISIANA 70801

January 30, 1979

DOCKET OFFICER
DATE 2/9/79
TIME

Docket Officer, Docket H-079
Room S6212, U.S. Department of Labor
Occupational Safety and Health Administration
Third Street and Constitution Avenue, N.W.
Washington, D.C. 20210

Gentlemen:

The attached document is submitted in response to the request for information on:

Occupational Exposure to 1,2-Dichloroethane (Ethylene Dichloride-EDC) published in 43 Fed.Reg. 56910 (December 5, 1978).

I appreciate the opportunity to submit this material.

Sincerely,

Gary Ter Haar

Gary Ter Haar
Director

GTH:ws

Attachment - 4 copies

SL 080815

A SUBMISSION

by Ethyl Corporation

in response to the request December 5, 1978 of Eula Bingham, Assistant Secretary of Labor, for information to be used in developing a Standard for:

1,2-DICHLOROETHANE

Note: The information given in the following pages addresses in turn each of the eleven categories of information requested in the Notice published in the Federal Register on December 5, 1978, p. 56910.

Ethyl Corporation
Baton Rouge, Louisiana
January 25, 1979

Background and Comments

1,2-Dichloroethane (Ethylene dichloride-EDC) is usually manufactured by the liquid-phase reaction of chlorine with ethylene in the presence of a metal halide catalyst. No by-products are formed. The crude EDC is passed over to a fractionating tower where the refined product is recovered in a yield of 96-98%. An alternative manufacturing process involves the reaction of ethylene, hydrogen chloride and air in a catalyst-bed made up of copper chloride with other metal chlorides. This "oxychlorination" process is preferred when an excess of hydrogen chloride is available.

EDC has been an important commercial chemical since the early part of this century. Since 1948, growth in commercial use has greatly expanded as this material came to be commonly used as a starting material for vinyl chloride. In 1972, 93% of the vinyl chloride produced in this country was based on EDC. Future usage of EDC will be greatly influenced by any OSHA and EPA regulations which are promulgated for EDC. The chemical industry, of course, is very interested that its workers are not over-exposed to noxious chemicals. At the same time, overly restrictive regulations increase production costs and can thereby jeopardize the workmen's jobs if particular chemical products become too high priced for the intended use.

Besides the use of EDC for the manufacture of vinyl chloride, in another major application Ethyl utilizes EDC as a component of the lead scavenger system in leaded gasoline. This application goes back to the 1920's when it was discovered that EDC and EDB (ethylene dibromide) can be blended in gasoline to produce a synergistic scavenger mix. The halide atoms react with the lead atoms during gasoline engine combustion to produce lead salts which temporarily vaporize and clear from the engine before solidifying.

The introduction of any alternative formulation of anti-knock additive would require additional time-consuming testing

and research in the current model lead-tolerant emission control systems. EPA would require a complete evaluation before acceptance of any new scavenger components under the terms of the recent amendments to the Clean Air Act. Thus, regulating EDC out of gasoline might result in eliminating the use of lead antiknock additives. Though the amount of leaded gasoline used in the U.S. is declining because of conversion to unleaded gasoline, the use of leaded gasoline is expected to continue to be of major importance because its markets are worldwide.

It is widely recognized that lead antiknocks are "energy savers". The elimination of EDC as a "scavenger" in leaded fuels would severely reduce the utility of this energy saving additive. The result would be a significant increase in the nation's crude oil usage. The production and utilization of unleaded gasoline results in 5 to 6% more crude oil usage as compared to leaded gasolines. Furthermore, the oil industry would be unable to produce the required volumes of gasoline during the next three or four years without lead antiknocks being available. This is because additional, very expensive, refinery process equipment would have to be installed to produce the necessary volume of high-octane blending stocks.

EDC has other important commercial uses. It is employed as a basic raw material for the manufacture of trichloroethylene, perchloroethylene, 1,1,1-trichloroethane (methyl chloroform), ethylene amines, vinylidene chloride and a variety of smaller scale uses.

The NIOSH Criteria Document Revision (DHEW-NIOSH Publication No. 78-211, September 1978) does not recognize that EDC may be a minor component of a solution in some of its uses. According to the definition used by NIOSH, "The term ethylene dichloride refers to all physical forms of the compound and its solutions". The document further defines "occupational exposure to ethylene dichloride" as work in any area in which ethylene dichloride is produced, stored, used, packaged or distributed. The combination of these two definitions would make the Standard all inclusive

for any material containing traces of EDC. This would work an unnecessary and unreasonable hardship on many businesses and industries. For example, every service station in the country would be required to monitor employees for personal exposures and to have preplacement physical examinations for all workers, annual physical exams, maintain records for 30 years, etc. There is no potential benefit from all this expense with regard to service station employee exposures to EDC. The concentration of EDC in gasoline is so low that there is no likelihood of anyone being exposed over the recommended 1 ppm TWA or 2 ppm ceiling.

While all attempts to measure EDC near gas stations or busy roads have shown levels to be below the limits of detection, extrapolation from EDB measurements lead to an estimation of well under 1 ppb. Therefore, it is unreasonable to require every service station in the country to incur the expense of monitoring, medical exams, and record keeping. There are likely to be other situations where EDC is a minor impurity in a product where similar unreasonable expenses will be required.

We doubt that the intention of the proposal for a regulation was to cover situations where exposures can be deduced to be insignificant. The regulations covering other known carcinogens specify a concentration in solution below which the regulation does not apply. It is only logical to use the same reasoning in developing an EDC regulation.

In the original benzene standard proposed by OSHA, there was no exemption of dilute solutions. This fact caused an unreasonable burden on many industries. OSHA recognized this and modified its proposal to exclude solutions containing less than 0.5% benzene. OSHA did exempt gasoline stations from the original standard. By the same logic, gasoline stations should be exempted from an EDC standard. However, to be consistent and reasonable, and to prevent unwarranted cost burdens on other industries, an exemption for low concentrations of EDC in solution should be specified.

1. Metabolism

It is essential that further metabolism research be conducted before promulgation of a revised TWA workplace standard for exposure to EDC.

EDC has been shown by NCI to be biotransformed in laboratory animals to a variety of metabolites, including monochloroacetic acid, which depresses enzymes including glutathione. However, no attempt was made to correlate dose dependent biological effects with degrees of enzyme saturation. Recent Dow studies have shown that a "no effect" level may indeed, be achieved in rats exposed to vinyl chloride, depending upon the degree of glutathione saturation. Such studies on EDC should demonstrate a safe level of exposure.

NCI made no attempt to demonstrate that the species or strains selected for their bioassay were appropriate. They should conduct sufficient metabolism studies to elucidate the exact in vivo biotransformation steps, pharmacokinetics, active forms, and in vitro correlation data.

A sound scientific study could be designed using the following steps:

A. In vivo rat metabolite profile characterized, and pharmacokinetic parameters identified, following administration by inhalation exposure. (Oral administration may lead to a different metabolite profile due to differences in membrane barrier metabolism of the stomach versus the lung.)

B. In vitro rat metabolites identified and correlated with in vivo metabolites. (In vitro systems could include rat lung, liver and kidney tissues).

C. In vitro human metabolites identified as in Step 2. Positive correlation would confirm that the rat was the most appropriate species. Negative correlation would indicate that other rat strains or animal species should be evaluated.

D. Conflicting results between Professor Maltoni and NCI could then be resolved by repeating the above steps by the oral route. Difference in metabolic

profiles and pharmacokinetic parameters could account for tumor formation in the NCI study and lead to identification of the active metabolite(s) involved.

2. Toxicity and Related - Carcinogenicity Studies

The conclusion drawn by NCI that EDC is carcinogenic in rats and mice is of questionable scientific validity for the following reasons:

A. Intubation of EDC over a long period of time is an unacceptable method of exposure to EDC. EDC is an acute and chronic irritant. F. Weiss[1] has reported that EDC erodes the membranes of the gastrointestional tract. It is not surprizing that continued irritation of the stomach with EDC produces an adverse response.

Robbins and Angell in "Basic Pathology"[2] state that "protracted chronic inflammation predisposes to squamous cell carcinomas; furthermore, neglected cases may become deeply invasive and metastasize to surrounding tissues". This type of inflammation was very probably elicited in the EDC animal feeding. NCI made no attempt to determine the acute or chronic irritating effect of EDC. Clearly this was a major deficiency of the study.

B. In addition to the squamous cell conclusions as discussed above, the NCI study does not show a dose response relationship among other neoplastic lesions, based on an analysis of the "target organs". The NIOSH criteria document indicates there is a dose response but this is incorrect. As shown in the table below, based on data from Table A1, A2, B1 and B2 of the NCI 1,2,Dichloroethane Assay Report (No. 107-06-2), a dose response is clearly absent.

HEMANGIOSARCOMAS

Rat Target Tissue	Low Dose Males	Low Dose Females	High Dose Males	High Dose Females
Spleen	6/50	2/50	2/50	1/50
Liver	1/50			1/50
Pancreas	1/50		1/50	1/50
Stomach	2/50			
Subcutaneous	2/50		1/50	
Large Intestine			1/50	

In regard to NIOSH's statement that there was a statistically significant increased incidence of adenocarcinomas of the rat mammary gland, it should be recognized that the incidence of spontaneous mammary gland tumors in the Osborne-Mendel rat has been reported by N.P. Page and others to be as high as 32%. NCI reported 10% in Controls, 2% at Low Dose and 36% at High dose, all within the distribution range of spontaneous tumors.

A dose/response relationship was also not demonstrated in the female B6C3F1 mice in regard to the mammary adenocarcinomas, (low-18%; High-15%) and endometrial tumors as indicated in the NCI report. Evaluation of the apparent dose/response in both sexes in regard to lung adenomas, as well as endometrial tumors, cannot be made without historical background data on spontaneous incidences.

C. Inhalation is the method of choice for the study of the potential carcinogenicity of EDC. Dr. Cesare Maltoni of the Cancer Center, Bologna, Italy, has, of course, carried out such a study. His rats and mice showed increases only in mammary tumors due to EDC exposure. These increases, he says, are not dose related and very characteristically run at about the 50% incidence level for each dose (150, 50, 10 and 5 ppm) as compared to about a 38% incidence level in untreated controls.

Dr. Maltoni explains that this increase in tumor-formation is, in his opinion, related to a chemical irritancy effect and to an upset in body chemistry and not to any inherent carcinogenicity of EDC. Dr. Maltoni reports that the mammary tumor increase is characteristic, and of the same order of increase, for a variety of other chemicals not considered to be carcinogens. Included in this group are such relatively innocuous chemicals as Fluorocarbons 11, 12 and 22.

Inherent in the NCI gavage approach is that no consideration is given to the fact that the bioavailability and pharmacokinetics of EDC are affected by the route of administration. As J.G. Wagner[3] states:

> "The metabolites formed after one route of administration may be different than those formed after another route of administration."

Wagner[4] says further:

> "Drug metabolism may take place in the gastrointestinal wall during the absorption process, in the liver, and in various tissues of the body, particularly in the lung and kidney."

These thoughts are further developed by H.M. Bolt[5]:

> "However, it has to be considered that biological action of a xenobiotic does not only depend on the biochemical target mechanisms of the latter, but is also largely influenced by pharmacokinetic factors."

The foregoing aspects may explain why the gavage study appears to show a carcinogenic effect while the inhalation data are negative.

Of considerable importance is the fact that workers are exposed to EDC by inhalation, not ingestion. Clearly the Maltoni study is more meaningful to worker health than the NCI study.

The NCI study also failed to consider possible indirect mutagenic effects upon intestinal bacteria. These effects may very well be the basis for the conflicting results obtained by Professor Maltoni. The EPA, moreover, recognized the need for further investigations before final conclusions are drawn. Food Chemical News announced in 1978 that the EPA felt that additional work was required on EDC. However, to date, NCI has not approved additional research.

References

1. Weiss, F., Arch. f. Gewerbepath. u Gewerbehyg., 15, 253 (1957).

2. Robbins, S.L. and Angell, M., "Basic Pathology", 2nd Ed., 1976, W.B. Saunders Co., p. 117.

3. Wagner, J.G., "Fundamentals of Clinical Pharmacokinetics", First Edition, 1975, Drug Intelligence Publications, Inc. p. 356.

4. Ibid, p. 34.

5. Bolt, H.M., "Pharmacokinetics of Vinyl Chloride", Gen. Pharmac. Vol. 9, 1978, pp 91-95.

3. Human Epidemiology

No human epidemiological study has been made. However, records of Ethyl Corporation contain the health histories of employees potentially exposed to EDC during the company's entire developmental and manufacturing experience with it. Our Medical Department has observed no unusual adverse health effects on workers exposed to EDC.

4. Medical Surveillance

Each employer should conduct a medical surveillance program for all employees who are or will be exposed to EDC and following emergency situations resulting in potentially hazardous exposure. The employer should provide each employee exposed to EDC in excess of the action level with the opportunity for medical examinations performed under the supervision of a licensed physician who has been apprised of reason for the examination and of the nature of the employee's work exposure.

Workers who are or may be exposed to EDC in excess of the action level should have pre-placement medical examinations and annual medical examinations with emphasis on the liver, kidneys, lungs, cardiovascular system, nervous system, gonads, and skin. Laboratory tests should include tests of liver function, a complete blood count, urinalysis, spirometry and any other tests the physician deems appropriate.

When the tests performed show abnormalities, the tests should be repeated as soon as is practical, preferably within one month. If, at the time the employee is examined, the physician advises withdrawal of the employee from potential exposure to EDC, the employee and employer shall be so advised by the examining physician.

Emergency Exposure - Each employee exposed to EDC during an emergency shall be afforded medical surveillance as determined by the examining physician to be appropriate.

5. Respiratory Protection

Full face piece, positive pressure air supplied respirators are normally used for EDC in the manufacturing areas where vapor concentrations are expected to be high. A full face-piece, organic vapor canister mask is allowed for emergency escape purposes. Half face-piece organic vapor cartridge masks are permitted in some operations where concentrations are not expected to exceed 500 ppm.

Personal and ambient air monitoring results at Ethyl facilities show EDC concentrations well below permissible limits (see Section 7). Therefore, respiratory protection is not required for routine job functions, i.e. collecting quality control samples and making unit rounds. Full face canister masks are located in the operating areas for emergency use only. Supplied air respirators are utilized for vessel entry or maintenance jobs where exposures to EDC are anticipated. Half face-piece organic vapor cartridge respirators are used in barge loading operations.

6. Use and Production Technologies

Engineering Controls, including...

Engineering controls are used to minimize workers' exposure to airborne levels of EDC. When new equipment is installed, the design provides for such controls. A routine maintenance program ensures that all engineering controls, ventilation and physical control systems are maintained in efficient working order at all times.

Special Process Equipment

A. All pumps in the processing area have mechanical seals.

B. Quality control sampling of process streams is conducted via a continuous circulating loop, using a three-way valve. This avoids the need to flush lengths of pipe to get a representative process sample, thereby eliminating large spills and splashes.

C. The field sample booth is equipped with a standard laboratory hood to control vapors during routine analysis.

D. The process areas are constructed as open structures to eliminate confined spaces where EDC concentrations would tend to accumulate.

E. The unit control room is situated remotely from the process area. Clean make-up air and air-conditioning is provided.

Ventilation -- The production area is located outside, and natural ventilation is obtained. All quality control samples are analyzed under standard laboratory fume hoods to reduce potential exposures.

Housekeeping -- Emphasis is placed on cleanup of spills, periodic inspection, repair of equipment and leaks, and proper storage of materials. Emergency escape routes are kept clear at all times. EDC process drains are diverted to a special collection pit for EDC reclaimation.

Sanitation Practices -- Emergency showers, eye-wash stations and hand-washing facilities are well marked and readily available in the work area. Any clothing accidentally wetted by EDC is removed immediately and the skin washed thoroughly with soap and water.

Protective Clothing -- Because EDC is a liquid under ambient conditions, impervious protective clothing is required for various jobs. During operations or maintenance procedures where splashing, spilling, spraying, etc., or skin contact could occur special clothing is required, i.e. when collecting quality control samples impervious gloves and goggles are mandatory.

Eye Protection -- Goggles are required during all tasks where eye contact with EDC is possible. Good hygiene practices are enforced at all times.

Warning Devices and Labels...

The following cautions and first aid advice is considered appropriate, and should be posted and disseminated in all appropriate places.

WARNING

HARMFUL IF INHALED, SWALLOWED OR ABSORBED THROUGH SKIN.
CAUSES EYE IRRITATION
Avoid breathing vapor.
Keep container closed.
Use with adequate ventilation
Avoid contact with eyes, skin and clothing.
Wash thoroughly after handling.

FIRST AID: If inhaled, remove to fresh air. If not breathing, give artificial respiration, preferably mouth-to-mouth. If breathing is difficult, give oxygen. Call a physician.

In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes while removing contaminated clothing and shoes. Call a physician. Wash clothing before reuse.

7. Employee Exposures

Number of employees exposed full time, BR - 36; Hou - 12
Number of employees exposed part time, BR - 114; Hou - 38

With few exceptions, exposures have generally been low e.g. <5 ppm. Area monitors indicated <3 ppm.

Area and personnel monitoring of Ethyl's Baton Rouge plant has produced the following specific data:

TABLE I

Workplace and Ambient Levels of EDC

Area	Concentration (ppm) Range	Mean	Comments
Ethyl - Baton Rouge (Hydrocarbon Manuf.)	0.1-5.6	1.6	33 Samples 23 Below 1 ppm
Ethyl - Baton Rouge (Hydrocarbon Maintenance)	1.6-13.5	5.7	3 Samples 2 Below 5 ppm Reboiler change out
Ethyl - Baton Rouge (TEL Manufacturing)	<0.02	-	2 Samples None Detected
Ethyl - Houston (CHA Section)	0.02-2.6	1.0	14 Samples 7 Below 1 ppm
Ethyl - Houston (Laboratory)	0.02-1.24	0.5	3 Samples 2 Below 1 ppm
Ethyl - Houston (TEL Manufacturing)	0.02 -0.24	0.06	9 Samples 8 Below 0.2 ppm
Ethyl - Houston (EDC Barge Loading)	0.3-3.4	1.4	6 Samples 3 Below 1 ppm

8,9. Technological and Economic Feasibility of Reducing Employee Exposure

Exposures of workers to EDC vapor can be minimized if certain standard procedures are followed at all stages of production. The following basic provisions can be incorporated into such operating procedures. As additional methods of control are devised, they can be implemented wherever appropriate.

Routine operation -- Where a local exhaust ventilation or collection system is used, it can be so designed and maintained as to minimize EDC concentrations in air. Air from the exhaust system must not be recirculated into the workroom. Good housekeeping practices should be exercised at all times. Smoking is prohibited in process areas, except in designated areas.

Abnormal/emergency operation -- When vessel-opening, or entry of equipment which may contain EDC, is required, appropriate special procedures should be employed. Any worker involved in these tasks should be required to use adequate personal protective equipment, including a respirator and protective clothing. A formalized written vessel entry procedure is established and followed. The appropriate respiratory protective equipment should always be available for use during emergencies. Fire fighting procedures have been established and appropriate equipment provided.

Cost of Compliance		10 ppm	1 ppm
Capital,	BR	$460,000	$655,000
	Houston	153,000	220,000
Annual,	BR	248,000	322,000
	Houston	83,000	108,000
Differential First Year Operating Cost,	BR	141,000	181,000
	Houston	47,000	60,000

Cost for operating at levels below 1 ppm become very high and lower levels are, we believe, unnecessary.

10. Analytical and Sampling Methods

Sampling Method

Collection Medium: SKC 600 mg charcoal tubes

Flow Rate: 100 cc/min.

Pump: DuPont constant low flow pump Model 125

Method: Collect in worker's breathing zone for minimum of 7 hours during working shift for personal samples. Stationary samples collected in same manner.

Calculation:

$$\frac{\text{total } \mu g \text{ found} \times 24.45}{\text{Vol. in l} \times \text{MW}} = \text{actual exposure ppm}$$

Analytical Method

Collection Medium: SKC 600 mg charcoal tubes

Eluant: Reagent grade carbon disulfide with pentane as internal standard.

Desorption Conditions: Cool eluant in dry ice, add charcoal from sample tube and place in wet ice bath for thirty minutes with occasional agitation.

Gas Chromatographic Conditions:

Chromatograph: Hewlett-Packard 5710 with flame ionization detector

Column: 1/8" x 25' 30% Se-52 on Gas Chrom Q, 80/100 Mesh

Injector Temperature: 150°C

Oven Temperature: 100°C Isothermal

Detector Temperature: 300°C

Carrier Gas: Helium

Flow Rate: 30 ml/min.

Analytical Precision: Unknown

Analytical Accuracy: ± 10%

Low Detectable Limit: 5 µg

11. Whether an ETS Issuance is Appropriate

The issuance of an Emergency Temporary Standard is not appropriate. There is no indication of any manufacturing or user emergency.

BF Goodrich
Chemical Division

The BFGoodrich Company
Chemical Division
6100 Oak Tree Boulevard
Cleveland, Ohio 44131
216-524-0200
William C. Becker
Division Vice President
Employee Relations
and Public Affairs

4

February 1, 1979

DOCKET OFFICER
DATE 2/9/79
TIME

Docket Officer
Docket No. H-079
Room S6212
U. S. Department of Labor
OSHA
Third Street & Constitution Ave., N. W.
Washington, D. C. 20210

Subject: OSHA request for information on 1,2-dichloroethane

Dear Sir:

BFGoodrich Chemical Division appreciates this opportunity to respond to OSHA's request for information regarding 1,2-dichloroethane (ethylene dichloride).

We have many years' experience in the manufacture of EDC and do not know of any evidence of a grave danger to the health of our employees, calling for immediate action. Therefore, it is our belief that there is no need for an emergency temporary standard for ethylene dichloride (EDC). We base this position on two facts.

- There is no scientific data, to our knowledge, to support imposing an emergency temporary standard.

- Our personnel monitoring has shown that we have already attained low levels of EDC exposure.

Following are answers to the questions you have posed.

Human epidemiology. BFGoodrich Chemical Division has manufactured and processed EDC at its Calvert City, Kentucky, plant for 15 years, converting it to vinyl chloride. We also make chlorine and ethylene at this site.

Therefore, our employee exposures at this plant tend to be mixed and few employees can be identified whose principal exposure would have been to EDC. Meaningful epidemiology study, at this point, is not possible.

Medical surveillance procedures. BFGoodrich Chemical Division believes that appropriate medical surveillance should be directed at identifying the effects of chronic exposures to EDC. Acute effects will be self-evident and readily identified with the exposure situation.

SL 080834

In looking for evidence of chronic toxicity, we feel medical surveillance efforts should be directed at examination of the liver and kidney, which are the organs principally affected. We believe the best means for identifying liver and kidney damage is by chemical examination of the blood and urine for evidence of organ damage. We also believe that the employee's health will be best protected by allowing the examining physician a wide latitude in the choice of tests to be used. We feel that requiring specific bio-chemical tests will tend to freeze the examination into a fixed format and will discourage physicians from regularly changing their examination procedures as new and better tests are identified in the course of medical progress.

An annual, interval history and appropriate bio-chemical tests for liver and kidney damage, would constitute an appropriate medical surveillance procedure. Specifically, we see no need or value in a "hands-on" examination by a physician except when the bio-chemical studies indicate some problem and the examination becomes a natural part of the follow-up examination.

Appropriate respiratory protection. At our Calvert City facility, EDC is manufactured and processed in a liquid state in open air operations. Almost all vinyl chloride manufacturing operations at Calvert City involve EDC. Physically, EDC is much less volatile than VCM. Therefore, the respirators already assigned to employees for vinyl chloride provide adequate protection against EDC exposure. The respiratory protection requirements for EDC should be selected in conjunction with present respiratory equipment required for vinyl chloride.

Our present vinyl chloride respiratory program consists of:

- Not over 1000 ppm - Type C, supplied air respirator continuous flow type, with half facepiece.

- Unknown, or above 1000 ppm - Open circuit, self-contained breathing apparatus, pressure demand type, with full facepiece.

While there might be some concern for eye protection using half-mask respirators, they can be, and frequently are, supplemented with monogoggles or a faceshield to provide suitable eye protection.

Production technology. Please refer to EPA-450/3-73-005-b entitled "Survey Reports on Atmospheric Emissions from the Petrochemical Industry, Volume II" and EPA-450/3-73-006-c entitled "Engineering and Cost Study of Air Pollution Control for the Petrochemical Industry, Volume 3: Ethylene Dichloride Manufacture by Oxy-chlorination."

Employee exposures. The Calvert City plant has five gas chromatographs for ambient area monitoring of EDC and VCM. Each GC has 10 sample collection points and each point is sampled and analyzed twice per hour, or a three minute cycle per point. Several points have multi-probes. In the EDC manufacturing area where there is the highest potential exposure, about 25 percent of the readings are greater than 5 ppm EDC, and 20 percent are greater than 10 ppm EDC.

The EDC manufacturing area employs about 50 people. A limited number of six-hour personnel samples there averaged 2.75 ppm, with a median sample of 2.27 ppm and a maximum of 8.96 ppm. The highest exposure job was the roving operator who averaged 3.33 ppm for 10 samples.

Reducing employee exposure and complying with complete 1,2-dichloroethane standard at the lowest level of exposure feasible. BFGoodrich believes that any exposure levels to be considered for comment must be specified before we can make intelligent comments on the amount of money to be invested in achieving those levels. Costs, as demonstrated by other standards, increase by orders of magnitude as lower levels of exposure are considered.

We chose, in conjunction with the VCM control program, to establish an internal target of five ppm EDC on a time weighted average. On the average, we met that goal. Since we do not see any need for changing the present OSHA standard, we have not estimated the cost of compliance with a new standard.

Analytical and sampling methods. We use the Bendix Flasher Method for personnel monitoring at our Calvert City plant. The combined sampling and testing error associated with personnel monitoring for EDC has been determined to be $\pm$ 17 percent.

Whether issuance of an emergency temporary standard is appropriate. An emergency temporary standard is authorized by law only when employees are exposed to grave danger to health, and the ETS is immediately necessary to protect employees from such danger. The Goodrich experience in manufacturing and processing EDC has not shown such a grave danger to our employees. Indeed, industry-wide, we know of no evidence of such danger. Results of the animal studies are conflicting. Although the National Cancer Institute gavage studies are positive, preliminary results on the Manufacturing Chemists Association (MCA) inhalation study conducted by Dr. Maltoni are negative. Preliminary MCA teratology study results do not support evidence of a grave danger. In summary, our experience in manufacturing EDC and our knowledge of the relevant facts are not consistent with the existence of any danger, let alone one which can be reasonably characterized as "grave."

As we said, it is the position of the BFGoodrich Chemical Division that no emergency temporary standard be issued at this time. We realize that there are other specific proposals now being considered by OSHA. However, the framework of the questions in this request for information makes it inappropriate to address other proposals and we assume the opportunity to comment on these will be afforded to us should OSHA choose to act in reliance on them.

Sincerely,

W. C. Becker

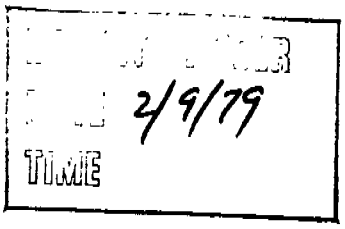
WCB:mm

SL 080837

5

Diamond Shamrock

Law Department - Chemicals



February 2, 1979

Docket Officer
Docket No. H-079
Room S-6212
U. S. Department of Labor, OSHA
Third Street and Constitution Avenue, N.W.
Washington, DC 20210

Re: 1,2-Dichloroethane (ethylene dichloride)

Gentlemen:

In response to your request for information dated December 5, 1978 (43 Federal Register 56910), we will submit to you as promptly as possible data and comments on the above matter.

Our submission will include exposure and toxicological data and economic and technological feasibility analyses, as well as comment on the appropriateness of issuing an Emergency Temporary Standard.

Additional time is required to organize our data and put it in context, so that our submission will be more fully responsive to your request, as well as to the recently published revised recommendations of the National Institute for Occupational Safety and Health.

At this time, we can say that we are unaware of any data, including the NCI data referred to in your request, which demonstrates the need for an Emergency Temporary Standard.

We estimate that our response will be completed within the next two weeks. In the meantime, should you wish to discuss this matter, please call me at (216)694-5268.

Very truly yours,

R. W. Hill
Senior Counsel

/njw

SL 080838

6

Shell Oil Company

One Shell Plaza
P. O. Box 2463
Houston, Texas 77001

Paul F. Deisler, Jr.
Vice President
Health, Safety & Environment

DOCKET OFFICER
DATE 2/9/79
TIME

February 2, 1979

Docket Officer, Docket No. H-079
Room S6212, U.S. Department of Labor, OSHA
Third Street and Constitution Avenue, N.W.
Washington, DC 20210

Dear Sir:

This letter and its attachments are submitted in response to the request for information on 1,2-dichloroethane (EDC) published December 5, 1978, at page 56910 of Volume 43 of the Federal Register.

We have had insufficient time to address fully all the complex issues raised in the EDC query and in companion requests for information also published on December 5, 1978. We anticipated this situation and asked for additional time to address these issues; a copy of our December 18 request is attached. Because we have received no reply, we are supplying the best answers possible in relation to EDC within the short response time available.

The attachments address the eleven questions presented at 43 F.R. 56910 and support the following positions:

1. The relevant EDC literature is inadequate to support the NIOSH-proposed limits for occupational exposures. Toxicology studies appearing in the literature are limited primarily to acute exposures; epidemiological studies usually are anecdotal.

2. No data exist to show that unreasonable risks to human health accompany exposures which comply with current standards.

3. Long-term EDC toxicology studies nearing completion are designed to help supply knowledge where deficiencies exist now.

4. NIOSH recommendations for EDC exposure standards cannot be supported because they place unjustified emphasis on exposure by gavage whereas the principal industrial exposure is by inhalation of low concentrations of vapor.

SL 080839

5. Available information does not support an emergency temporary standard for EDC exposures.

We urge that OSHA re-examine available literature and evaluate the relevance of the various elements found there. We believe that such a re-examination will lead OSHA to agree with our conclusion that compliance with current occupational exposure standards for EDC is free of unreasonable risk to human health. We urge OSHA to await public scientific review of EDC toxicology studies now nearing completion and that OSHA conduct a "Regulatory Analysis" as described in Executive Order 12044.

Very truly yours,

P. F. Deisler, Jr.
Vice President
Health, Safety and Environment

Shell Oil Company

One Shell Plaza
P O Box 2463
Houston, Texas 77001

ATTACHMENT 1

December 18, 1978

Honorable Eula Bingham
Assistant Secretary
Occupational Safety & Health Administration
U. S. Department of Labor
Third Street and Constitution Avenue, N.W.
Washington, DC 20210

Dear Dr. Bingham:

The Shell Oil Company and its subsidiary, Shell Chemical Company, wish to comment on your questions concerning epichlorohydrin and 1,2-dichloroethane (43FR56907 et seq). The details requested in the announcement are complex and varied. We feel that the time deadlines of January 19, 1979, and February 5, 1979, respectively, for the two chemicals will not permit an appropriately detailed reply. The time frame is further exacerbated by the effect of the Christmas holiday season in which many of those who will be involved in developing the replies are not now available, nor will they be until after the first of the year. Accordingly, we request the granting of a 60-day extension beyond the stated respective deadlines for comments.

Very truly yours,

/s/ Howard L. Kusnetz

Howard L. Kusnetz, Manager
Safety & Industrial Hygiene

SL 080841

(1) Metabolism, including intermediate as well as final metabolites

The National Institute for Occupational Safety and Health (NIOSH), in its March 1976 Criteria Document, states that "No information on metabolism of ethylene dichloride by humans was found in the literature" (1). Like NIOSH, we are unaware of information concerning human metabolism of EDC. Studies involving metabolism of EDC in animals are few in number and we are unable to augment the list of literature references contained in the NIOSH Criteria Document (2).

OSHA is aware of ongoing animal metabolism studies supported by the Manufacturing Chemists Association (MCA) and being conducted at the Mario Negri Institute in Milan. These particular studies began about a year ago and represent one segment of a comprehensive series of studies of various aspects of EDC toxicology being sponsored by the MCA. It is MCA's policy to provide final reports promptly to interested agencies. Shell is an active participant in these MCA activities.

(1) Criteria for a recommended standard .... Occupational Exposure to EDC, NIOSH, March, 1976, p. 72.

(2) Ibid, pp 68-72.

(2) Toxicity, tumorigenicity, carcinogenicity, teratogenicity and/or mutagenicity, including the effects of potential co-factors as related to each of these

The Manufacturing Chemists Association (MCA) is sponsoring long-term animal tests involving inhalation of EDC. This work, being conducted by Dr. Maltoni, is nearing completion: 12-month exposures at several concentration levels are complete and associated pathology studies are progressing. It is Shell's expectation that results will be reported by the second quarter of 1979.

A second MCA-sponsored study focuses on teratology: this study is being performed by Dow Chemical Company and we expect a final report by the second quarter of 1979.

A third MCA-sponsored study involves reproductive effects. Exposures for the reproductive studies have been completed and skeletal evaluations are in progress. We expect that this study will be completed by the third quarter of 1979.

Final reports will be provided promptly to interested agencies. Shell has participated in each of these MCA activities by contributing both financial and scientific support.

We have no information to offer on the effects of co-factors and have been unable to find any suggestions of EDC-related co-factors in the literature.

(3) Human epidemiology (employee populations and those otherwise exposed)

Shell has no epidemiological data relating only to EDC exposures. Those epidemiological data which Shell has reviewed are confounded by simultaneous exposures to other agents. Those studies labeled as "epidemiologic" in the NIOSH Criteria Document (3) are largely anecdotal in character and often involve simultaneous exposure to other chemical agents considered to be toxic (e.g., carbon tetrachloride, benzene). Another confounding factor is the lack of data concerning individual smoking histories; this factor can have an impact on results. Unfortunately, some of the clinical data noted in the NIOSH Criteria Document under the epidemiology section are incomplete and it may not be possible to correct these deficiencies because the data were collected a long time ago.

(3) Criteria for a recommended standard .... Occupational Exposure to EDC, NIOSH, March, 1976, pp. 46-57.

(4) Appropriate medical surveillance procedures

Medical surveillance procedures for EDC are difficult to define in the absence of an evaluation of the final results from Dr. Maltoni's inhalation study. Pending the outcome of that work, Shell is unable to define appropriate medical surveillance procedures if, indeed, any appear to be scientifically indicated. Shell's medical surveillance objectives include the application of appropriate medical techniques and procedures of modern preventive medicine. Our philosophy in medical surveillance is that "single-purpose" tests do not substitute for more complete medical profiles once scientific justification for surveillance is established.

Shell's medical surveillance programs currently include virtually all our employees routinely exposed to EDC despite the fact that we have no specific EDC medical surveillance program. People exposed to vinyl chloride and epichlorohydrin are included in special annual medical surveillance programs; it is these populations which are likely to experience EDC exposures also. It is possible that personnel having occasional potential exposures to EDC might not be included in one of our annual special-surveillance programs. These individuals are encouraged to participate in our voluntary periodic examination program.

(5) Appropriate respiratory protection

A standard for regulation of EDC exposure should provide for employee protection through use of appropriate respiratory protection.

The NIOSH EDC Criteria Document recommends only air-supplied equipment. If the NIOSH recommendations are adopted, air purifying respirators would not be permitted, except for evacuation or escape, because of the "poor warning properties" of EDC at the recommended environmental limit of 5 ppm TWA and 15 ppm over 15 minutes (peak). The Document reports that the odor threshold of EDC is 3 to 100 ppm based on three literature references. Our experience indicates that the odor threshold is much closer to 3 ppm than 100 ppm. It appears therefore that more definitive information is required to substantiate the claim of poor warning properties.

However, regardless of the odor threshold, we believe that the decision on whether to permit air purifying respirators should be based on the efficiency of these devices in removing EDC from ambient air, and their service life. If removal efficiency and service life are adequate to protect employees, they should be permitted. Research on service life of chemical cartridge respirators for organic vapors in general (Nelson, et al, Am. Ind. Hygiene Assoc. J. 37:514) and EDC in particular (Nelson, et al, Am. Ind. Hygiene Assoc. J. 35:391) indicates that breakthrough of EDC will not occur over a 10-hour shift with an ambient level of 100 ppm, assuming moderately heavy exertion (37 L/min breathing rate) for the entire shift with respirator cartridges containing 80 grams of carbon per pair of cartridges.

(6) Uses and production technology

Shell's primary use of EDC is as a chemical intermediate which is subsequently converted to vinyl chloride. More than 95 percent of our needs for EDC are supplied by our own manufacture. Sales of EDC by Shell to others have been on an occasional basis only (mostly for export) and have amounted to less than one percent of our production.

Shell's second use of EDC is as a gasoline additive. None of our EDC production is used directly in motor gasoline. Rather, we purchase an additive "cocktail" containing pre-mixed EDC, alkyl lead, and ethylene dibromide from one or more of several suppliers.

Production technology involves the direct chlorination of ethylene and the oxychlorination of ethylene with hydrogen chloride. This technology is licensed from another party and we are not at liberty to disclose the relevant details.

(7) Employee exposures (actual or potential) in each use and production facility, including: (a) the levels and specific conditions of such exposures. (b) the number of employees involved in each exposure situation

At about ten Shell blending locations, a gasoline additive "cocktail" is blended with appropriate hydrocarbon streams to prepare motor gasoline (4). The premixed additive "cocktail" contains alkyl lead, a class of compounds long regarded as toxic. As a result of concerns over potential exposures to alkyl lead, work practices in gasoline blending facilities have, for many years, been characterized by extraordinary caution. Gasoline blending is highly automated and the premixed additive is metered and blended into the gasoline via in-line blending. It is not surprising, therefore, that our attempts to obtain reliable and quantitative measurements of employee exposure to EDC at gasoline blending facilities have not been successful because ambient EDC levels are below our limits of detection.

At Shell's two EDC production facilities, we have compiled personal monitoring data involving 2199 samples over the three-year interval 1976-77-78. These samples cover all aspects of our EDC production activities, both normal operations and shutdowns, and all job categories, including operator, shipper and various crafts. Analytical procedures and sampling techniques are recognized standard methods. The results in the following table are from "lapel-type" samples of ambient air and many samples were collected while the person was wearing an approved respirator. The actual employee exposures were lower than the levels reported below for the ambient air. Hence the levels recorded serve only to indicate the potential exposure which would have occurred in the absence of a respirator.

Personal Monitor, 8-hour TWA	Number of Samples	Percent of Samples	Cummulative Percent of Samples
< 1 ppm	1459	66.3	66.3
1-5 ppm	571	26.0	92.3
5-10 ppm	95	4.3	96.6
10-50 ppm	66	3.0	99.6
> 50 ppm	8	0.4	100

Exposure situations fall into two main categories which will be labeled "normal" and "occasional" for the purposes of this answer. In the "normal" category are those exposures of operators and maintenance personnel "normally" assigned to EDC production facilities. A total of approximately

(4) See attachment A(6), supra.

70 operators is "normally" involved at the two Shell sites and work activities involve potential EDC exposures during the entirety of the work week. In addition, approximately 70 maintenance personnel are assigned to EDC production units: of this total, about one-half finds week-long duties at the EDC unit and the other half rotates to other areas outside the EDC facilities where their skills are required.

"Occasional" exposures to EDC occur during shutdowns of production units (approximately 25 days per unit per year) when additional maintenance personnel refurbish operating units. "Occasional" exposures also will be experienced by non-EDC personnel who enter EDC production facilities sporadically and by labaratory personnel who use or test EDC.

(8) Technological and economic feasibility of reducing employee exposure

(9) Economic and technological feasibility of complying with a complete 1,2-dichloroethane standard at the lowest level of exposure feasible

It is not possible to answer these questions satisfactorily at this time because meaningful estimates of the costs of complying with possible OSHA actions regarding EDC require:

1. Definition of the target level(s) of interest;

2. Detailed target-oriented engineering designs with subsequent cost estimating.

We do not believe that such studies should be undertaken until there is some reasonable showing of need. However, we do have some general comments to offer.

Our deligent efforts to reduce employee exposures to vinyl chloride and other chemicals have controlled potential EDC exposures to very low levels. Virtually all personal monitoring data (5) show that employees encounter work-place environments having ambient air levels of EDC well below existing standards. Furthermore, actual exposures are even lower because respirators are worn frequently in those work areas where significant inhalation exposures of EDC are possible.

In theory, it is possible to place employees in continuously-worn life support systems akin to space suits but practical experience indicates this is totally impractical in an EDC manufacturing environment. Such "space suits" are awkward and pose new perils to those encumbered with them. In theory, it is possible to encase a petrochemical unit in an enclosure, but this too is totally impractical from the standpoint of operating the facility. In addition, such enclosures can create additional dangers to employees. We believe this action would be an unwarranted waste of resources.

Looking to the specifics of our EDC production facilities, monitoring experience has shown that the potential for high exposures is greatest at two locations near the end of the processing scheme. One is the EDC recovery facility and the second is at the furnaces and reboilers. These locations have a common feature - both contain coke deposits which are exposed during shutdowns and other de-coking procedures. Coke has a relatively high capacity for adsorbing EDC, and when vessels and/or lines are opened, the exposed coke desorbs EDC. We know of no way to eliminate this phenomenon. Therefore we use respirators in these operations since this is the only practical way to avoid EDC exposures which would otherwise be objectionably high.

(5) See attachment A(7), supra.

(10) Analytical and sampling methods used and evidence of their precision and accuracy

EDC analysis in our Industrial Hygiene Laboratory is according to NIOSH Method S122. This involves a charcoal sampling tube, desorption with carbon disulfide and analysis in a gas chromatograph equipped with flame ionization detection.

With this method we have obtained satisfactory calibration at the 0.5 ppm level based on a 10 liter air sample. The desorption efficiency at the 1 ppm level is satisfactory ($\geq$ 88%); however we do not know if desorption efficiency will be a limiting factor at lower EDC levels.

Any EDC standard should allow flexibility in analytical and sampling method as long as acceptable precision and accuracy can be achieved. For example, our manufacturing locations presently use a plastic bag/GC technique as part of their exposure monitoring for a variety of airborne substances. This flexibility should be encouraged as long as acceptable results are obtained.

(11) Whether issuance of an Emergency Temporary Standard is appropriate

Section 6(c) of the OSH Act is specific in regard to when an Emergency Temporary Standard (ETS) is appropriate. The Secretary must find that a substance poses a "grave danger" to workers and that the ETS is "necessary to protect employees". NIOSH's Revised Recommended Standard ... Occupational Exposure to Ethylene Dichloride (6) is based primarily on animal tests which have, at best, a tenuous relationship to occupational exposures to EDC. The animal tests using rats and mice involved intragastric intubation of EDC in amounts equivalent to 5 and 10 percent of body weight. Occupational exposures to EDC involve drastically different quantities of material relative to body weight and a completely different route of exposure.

Occupational exposures to EDC are low and involve inhalation. NIOSH itself considers "... the evidence for a carcinogenic potential of ethylene dichloride via inhalation to be inconclusive" (7). Despite intense scrutiny, there is no evidence that occupational exposures which comply with existing OSHA regulations pose an unreasonable risk to human health. Hence exposure to EDC at levels which meet current regulations do not pose a "grave danger".

Under these circumstances, an ETS is inappropriate and can not be supported. It is especially inappropriate to undertake such precipitous action in view of comprehensive and multifaceted EDC studies underway and nearing completion under the auspices of MCA.

(6) Revised Recommended Standard ... Occupational Exposure to Ethylene Dichloride (1,2-Dichloroethane), NIOSH, September, 1978.

(7) Ibid at p. 5.

7

Stauffer Chemical Company

Westport, Connecticut 06880 / Tel. (203) 222-3000 / Cable "Staufchem"

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

February 5, 1979

DOCKET OFFICER
DATE 2/9/79
TIME

Docket Officer
Docket H-079
U.S. Department of Labor
Third Street & Constitution Ave., N.W.
Washington, D.C. 20210

Dear Sirs:

This letter is to confirm a telephone conversation on January 24, 1979 between Mr. Robert Cluck on behalf of OSHA and the undersigned. Mr. Cluck assured me that the February 5, 1979 deadline for information on ethylene dichloride (see Fed. Reg. December 18, 1978) could be informally extended to March 5, 1979. Additional time will also be necessary to respond to a new NIOSH revised recommendation for EDC, published on January 4, 1979.

Based on the foregoing, Stauffer Chemical Company intends to respond to the December 5, information request and the revised NIOSH recommendations by March 5, 1979.

Very truly yours,

STAUFFER CHEMICAL COMPANY

Gary L. Ford
Law Department

GLF:mep

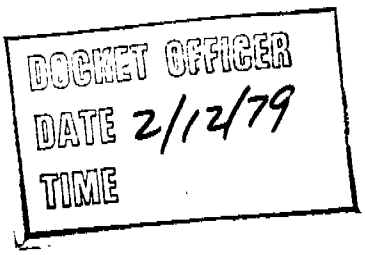
S[illegible]0352

8

American Petroleum Institute
2101 L Street, Northwest
Washington, D.C. 20037
202-457-7228

Daniel B. Rathbun
Vice President

February 5, 1979



Docket Officer
Docket No. H-079
Room S6212
U.S. Department of Labor
Occupational Safety and
Health Administration
Third Street and Constitution Ave.
Washington, D.C. 20210

Dear Sir:

API is pleased to respond to OSHA's request for information on ethylene dichloride (EDC) (43, Federal Register, 56910, December 5, 1978). The petroleum industry's interest in EDC stems from its use in catalytic reforming operations as well as its use as a lead scavenger in leaded gasoline.

In catalytic reforming, EDC is injected in small measured amounts into the feed stock to prevent contaminants from poisoning the catalyst. The EDC once injected, is decomposed in the reforming operation. The only potential exposure to EDC occurs when it is transferred to storage tanks prior to injection. A recent trend in the petroleum industry is to substitute other chemicals for EDC in reforming operations, which, like EDC, provide a source of chlorine which is the necessary agent to reduce the likelihood of poisoning the catalyst.

The second and more important use of EDC in the petroleum industry is as a lead scavenger in motor gasoline. EDC exposure within refineries associated with lead-blending operations and subsequent exposures to EDC in motor gasoline handling operations are extremely low.

EDC, along with ethylene dibromide (EDB), is part of an antiknock package which also contains organic lead. This package is normally provided in premixed form to refiners by antiknock suppliers. The precautions which are taken to prevent exposure to the lead also control exposure to the EDC. This package is handled under tightly controlled conditions, and when blended directly into motor gasoline, the EDC and lead are diluted to a level which does not pose a hazard. This dilution and the precautionary measures taken distinguishes EDC exposures in the petroleum industry from exposures in other industries.

An equal opportunity employer

In response to OSHA's March 17, 1978,, Federal Register notice, API conducted a short-term program to monitor EDB. As part of the same study, we attempted to monitor EDC; however, the limits of the analytic technique used made it impossible to detect EDC at the extremely low concentrations present around service stations and bulk terminals. A rough estimate of EDC exposures can be made using the data gathered in API's EDB monitoring program.

The "lead package" contains equal weights of EDB and EDC; the vapor pressure of EDC is 5.75 times that of EDB. Given this information, EDC exposures under "ideal" conditions is 5.75 times the EDB exposure.

The following test results on EDB were reported to OSHA on May 16, 1978:

> Exposures in service stations (based upon approximately 30, full shift samples) ranged from 0.24 ug/m^3 to 0.90 ug/m^3 under normal operating conditions. One sample was 2.90 ug/m^3 when a customer drove off with the hose still in the tank causing a large spill. In addition, sampling data was obtained from refineries and marketing terminals. Exposures in refinery blending operations were 0.2 ug/m^3 and in unloading the TEL [tetraethyl lead] package were 3.2 ug/m^3. Exposures in marketing (tank truck bottom loading) were 0.2 to 0.8 ug/m^3.

Extrapolating from the EDB test data, it is estimated that EDC exposures are:

Service Stations	1.38 ug/m^3 to 5.18 ug/m^3
Refinery Blending	1.15 ug/m^3
TEL Package Unloading	18.4 ug/m^3
Marketing	1.15 ug/m^3 to 4.6 ug/m^3

After reviewing the National Cancer Institute study and the NIOSH Criteria Document on EDC, we have concluded that the scientific evidence which has formed the basis of the Federal Register notice on EDC is extremely weak. I have attached a review of these two documents which API has prepared. The major conclusion of this review is that, based upon the data presently available, a valid determination of the carcinogenic potential of EDC can not be made.

SL 080854

A standard for EDC, when developed, must consider the unique characteristics present in industries' various applications of EDC. Requirements must be tailored to suit particular situations for manufacture or use. A standard which treats all situations as if they were identical results in unnecessary breadth of regulation and is wasteful of society's limited resources. The exposure limit when set should be based on sound scientific criteria. Ancillary requirements involving medical surveillance and monitoring should be structured to support implementation and maintenance of the appropriate exposure limit. Finally, the standard, as a whole, should ensure that the placement of regulatory burdens is necessary to maintain worker health, appropriate in the work setting affected, and consistent with the best use of society's limited health resources.

Sincerely,

Daniel B. Rathbun

COMMENTS OF AMERICAN PETROLEUM INSTITUTE (API) TO OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION (OSHA) REQUEST FOR INFORMATION ON ETHYLENE DICHLORIDE

API believes that any alteration of the current standard on ethylene dichloride (EDC) would be premature due to the inadequacies in the National Cancer Institute study upon which the OSHA request for information document is based. API believes that before the question of EDC's carcinogenicity can be satisfactorily answered, the deficiencies in the NCI study outlined below must be corrected, and an adequately controlled scientific study must be conducted.

A. Chemicals - Analysis of the EDC utilized in the study "suggested a purity greater than 90 percent and showed the presence of 11 minor contaminants." (Page 5) This indicates that up to 10 percent of the chemical fed to the animals were other contaminants which could be carcinogenic. The dosages given animals utilized in the study ranged from 47 mg/kg/day to 299 mg/kg/day. (Page vii) Thus, the animals could conceivably be receiving between 4.7 mg/kg/day to 29.9 mg/kg/day of contaminants. With no analysis given of the 10 percent contaminants, it is impossible to attribute to EDC any effects observed.

B. Dosage Preparation - The report states that "the solutions given the animals were considered generally stable for ten days under the indicated storage conditions." (Page 5) Although stability studies were performed on the pure chemical, no such studies were performed on the chemical with the vehicle. As such, it is impossible to assess whether there was significant chemical breakdown and in fact the percentage of contaminants was even higher than 10 percent.

C. Statistical Analysis - API would initially point out that the "Cochran-Armitage Test" referred to (page 17), is, in reality, a chi-square test developed by Cochran with a variation suggested by Armitage. This procedure as utilized in this report apparently attempts to analyze whether there is a linear trend of greater numbers of tumors with increasing dosage. The procedure could be used to demonstrate a dose-response relationship. The data presented in the report is not sufficient for independent calculations of the figures presented. We are unable to determine the calculations utilized to obtain the P value for pooled vehicle controls as the P must be obtained by some comparison to historical controls utilized in the Hazleton Laboratories. No data is presented on these historical controls, if, in fact, this

1/ Bioassay of 1,2 dichloroethane for possible carcinogenicity; USDHEW, PHS, NIH, NGI; Tech. Report #86; 1978

2/ International Agency for Research in Cancer; monograph, 139, C1977

is the manner in which the P was determined. Furthermore, in examining Tables 3-6, in many instances the P of the pooled control value is a highly significant difference in tumor incidence as compared to the historical controls. NCI has the burden of explaining these mystifying results. If there is no rational explanation for the pooled control group developing a significant tumor incidence as contrasted to the historical control, it cannot be unequivocally stated that tumors developed by animals in a group given EDC were due to administration of the chemical.

We would further point out that the tumor incidence found in the untreated animals was completely dismissed in the analysis presented. In some instances, there appears to be significant tumor incidence in the untreated controls as contrasted to the vehicle treated controls. These results should have been explained. The report states "two types of control groups were used . . . and a pooled vehicle control group which combined the vehicle controls from the studies of 1,2-dichloroethane, 1,1,2-trichloroethane, and trichloroethylene. The pooled control rats were of the same strain, were housed in the same room, were tested concurrently for at least one year, and were diagnosed by the same pathologist." (Page 17) The report does not state whether the pooled control rats were from the same batch and whether they were all of the same age.

We would further point out that it is strange that the mice were tested with significantly higher dosages than the rats. It should also be noted that the mice that developed tumors had primarily been treated with such dosages. It is also noted that rather than treating with a specific dose through the duration of the experiment, the dosages given were "time weighted". That is, an initial dosage was given, the dosage was lowered for a period of time, and then the dosage was increased above the initial dosage. We suspect, in the absence of further elucidation, that the reason for application of this unorthodox procedure was that it was necessary to give the animals a lower dose in the second stage of the experiment because they were experiencing highly toxic reactions. When the animals had sufficiently recovered, apparently the dosages were once more significantly increased. This would suggest that the initial dosages given overwhelmed the metabolic systems of the animals, thereby producing results which are highly suspect.

We will now concentrate on discrepancies noted in the raw data and the test results reported in the tables. In Table A-1, dealing with the male rat, no hemangiosarcomas in the circulatory system are noted. Yet Table 3 lists seven hemangiosarcomas of the circulatory system. The total of all hemangiosarcomas listed in Table A-1 is nine.

In a discussion of the circulatory system of the female rat, no hemangiosarcomas are reported in the appendix while four are reported in the table.

We also question whether it is justifiable to add the cumulative numbers of tumors of adenocarcinoma and fibroma. Neither of these tumors alone show a linear dose response. The response of the high dose and lack of response in the low dose in the adenocarcinoma suggest a threshold effect. The data on the fibroma suggests mitigating effects and does not yield a true dose response. We would further point out that the onus is on NCI to show evidence that fibroma and adenocarcinoma results should be combined. If one considers combining all tumors, one can easily determine by performing statistical analysis that in experiments involving male and female rats, the total tumor incidence is not significant. Such statistical analysis would compare untreated with low and high dose animals. While no tumors in male mice are highly significant, no dose response is apparent. Such high dosage effects argue mild carcinogenicity at best. It should also be noted that the first tumors were observed at 81 weeks when the animals were receiving 1.5 times the time weighted dosage. The low dosages are non-significant. We would also question the validity of combining data from lymphomas and polyps.

D. Conclusion - We conclude that because of the deficiencies in the NCI study, the data cannot be used to determine whether or not EDC is carcinogenic. The impurity of the chemical, discrepancies between the raw data and data reported in the tables, lack of explanation of statistical analysis utilized, lack of explanation of the differences in incidence of tumors in untreated controls and vehicle treated controls and highly irregular data shown in the tables often showing no linear dose response effect would tend to invalidate any results that might otherwise be called conclusive. Because of the irregularities in this study, it is clear that no determination or extrapolation of possible carcinogenicity of EDC to humans can be made.

Comparison with Properties of Ethylene Dibromide

While ethylene dichloride and ethylene dibromide are structurally similar and thus in some respects have comparable physical properties, the toxicological properties vary considerably as the following discussion shows. Because of this, no attempt should be made to apply an ethylene dibromide standard to ethylene dichloride.

Carcinogenesis

While we question the validity of the NCI report on ethylene dichloride, it should be noted that the number of tumors produced in both rats and mice by ethylene dichloride was significantly lower than those produced by ethylene dibromide. Thus, while studies indicate that ethylene dibromide may be carcinogenic, there is no basis for deciding that ethylene dichloride is either non-carcinogenic or is a very mild carcinogen. This statement was echoed in a report from the National Cancer Institute (1) "1,2-dichloroethane was much weaker (emphasis added) than the analogue (1,2-dibromoethane) and induced only a few stomach tumors in rats."

Mutagenicity

Ethylene dichloride also appears to be much less mutagenic than ethylene dibromide. In a recent study by Rannug (2) involving revertant mutation of E.Coli and Salmonella Typhimurium, ethylene dibromide was found to be second highest in mutagenic activity of a group of halocarbons tested in E.Coli. In Salmonella, ethylene dibromide was shown to be extremely mutagenic. In both of these studies, ethylene dichloride induced the least number of mutations of all components tested. In Salmonella, TA1535, ethylene dibromide (10 micromoles) induced 1438 revertants. Ethylene dichloride at this concentration induced 54 revertants. In the revised Criteria Document (3), the work of Rannug (4) is cited as listing ethylene dichloride as a "moderate mutagen along with a potent mutagen when applied together with liver enzymes." However, this work was published in 1977, a year earlier than Rannug's more recent work on ethylene dichloride (referred to above) where it was suggested that ethylene dichloride might be mildly mutagenic.

Teratogenicity

The studies performed to date on ethylene dichloride have not shown any teratogenic effect although they have shown some effects on reproduction and fertility. In a study (5) where chickens were given 250 and 500 ppm EDC in mash for a period of two years, no effect was seen on growth, semen characteristics or fertility in chickens. A tolerance of 100 ppm in the diet was recommended. The authors found similar results with no teratogenicity in studies on the rat (6). Vozovaya (7-9) has found various effects of EDC alone and with gasoline inhalation exposure in rodents. The author found decreased fertility, increased number of still births, and decreased viability of the progeny. It is stressed, however, that the concentrations of EDC used were exceedingly high (e.g. 400 ppm). In addition, the author observed no teratogenic effects. On the basis of the work to date, it is

suggested that EDC is not teratogenic and may have only a mild effect on reproduction and fertility at high concentrations. Further work is indicated.

It should be stressed that the majority of pathological effects discussed in the initial NIOSH Criteria Document (10) were based on tests involving high concentrations of EDC. It should be further noted that the data taken from the NCI report and used in the revised criteria standard (3) has been incorrectly reported. The dosage given in mice (page 7) was approximately 100 and 200 mg/kg; not 50 and 100 mg/kg as reported.

REFERENCES

1. Weisburger, E. K.; Env. Health Perspect, 21, 7, (1977)

2. Rannug, U. et al; Chem-Biol. Interact, 20(1), 1, (1978)

3. NIOSH; Revised Recommended Standard ... Occupational Exposure to Ethylene Dichloride (1,2-dichloroethane) September, 1978

4. Rannug, U. et al; Toxicol. Environ Health, 2, 1019, (1977)

5. Alumot, E. et al; Food Cosmet. Toxicol. 14, 111, (1976)

6. Alumot, E. et al; Food Cosmet. Toxicol. 14, 105, (1976)

7. Vosovaya, M A.; Gig. Sawit, 7, 25 (1974)

8. Vosovaya, M. A.; Gig. Tr. Prof. Zabol., 7, 20, (1975)

9. Vosovaya, M. A.; Akush. Ginekol, 9, 66, (1973)

10. NIOSH; Occupational Exposure to Ethylene Dichloride (1,2-dichloroethane) March, 1976

9

DOW CHEMICAL U.S.A.

BARSTOW BUILDING
2020 DOW CENTER
MIDLAND, MICHIGAN 48640

February 5, 1979

DOCKET OFFICER
DATE 2/12/79
TIME

Docket Officer
Docket No. H-079
Room S 6212
U. S. Department of Labor
OSHA
Third Street and Constitution Avenue, N.W.
Washington, D.C. 20210

SUBJECT: Request for Information on 1,2-Dichloroethane, Federal Register, Vol. 43, No. 234, December 5, 1978, page 56910 - Docket No. H-079

Dear Sir:

This correspondence is in response to the above referenced request for information on 1,2-dichloroethane (EDC).

The Dow Chemical Company believes that the available data does not warrant the issuance of an Emergency Temporary Standard for EDC.

In reviewing the animal carcinogenicity data base on EDC, we are faced with the widely divergent results of the National Cancer Institute gavage study, which showed positive results in rats and mice, and those of Professor Maltoni's inhalation study, co-sponsored by a group of U.S. producers (under the auspices of the Manufacturing Chemists Association (MCA)) and European EDC producers, which produced no carcinogenic response in rats and mice at exposure levels up to 150 ppm. While the results of both studies must be considered for possible regulation of EDC, it is well-documented that in the typical occupational setting, inhalation is by far the predominant route of exposure to EDC. Therefore, the Maltoni study is more applicable to judging possible human cancer risk due to EDC. We believe the only conclusion that could be drawn from the inconsistent results of the Maltoni and NCI studies is that, at most, EDC might be a relatively moderate to low potency carcinogen. Until the reasons for the anomaly of these two study results can be determined, perhaps due to the differing routes of administration, peak versus continuous dose, or other differences, we believe that any action by the agency to regulate EDC would be precipitous and unnecessary to protect the worker.

SL 080862

In regard to human experience, we know of no reports of human cancer associated with EDC exposure, even though this material has been manufactured and used in large volumes for over 35 years, with thousands of workers exposed for long periods of time. Industry has long been aware of both the acute and chronic toxicity of EDC, and has taken appropriate precautions to protect employees from what have been recognized as the symptoms and effects of overexposure to this material. (See Attachment A, for example). If there indeed was a causal relationship between EDC exposure and cancer, it would have been recognized by now. Furthermore, since the largest percentage (approx. 80%) of EDC is used for vinyl chloride (VCM) manufacture, the occupational exposure controls instituted for VCM 5 years ago have resulted in a parallel reduction of EDC exposures. Therefore, any possible risk of EDC exposure has already been reduced in a significant portion of the workplace where EDC is present.

Because of the major ongoing toxicity research on EDC which will be completed within the year, we believe that any regulatory action should be deferred until the results of this research are available, so that a better-informed decision can be made. We would like to bring to your attention the studies being conducted under the auspices of the MCA as part of the current research program on EDC. These include:

1. The previously mentioned Maltoni inhalation study on Sprague-Dawley rats and Swiss mice, exposing the animals to 0, 5, 10, 50, and 150 ppm EDC, 7 hrs./day, 5 day/week, for 18 months. This study is completed and a final report is expected from Dr. Maltoni shortly.

2. Clinical Chemistry determinations on animals exposed by Professor Maltoni, conducted by Dr. Federico Spreafico of the Mario Negri Institute in Milan, Italy, which is also completed and a report expected soon.

3. Metabolism work by Dr. Spreafico at Mario Negri, to be completed in 1979.

4. A teratology study conducted at Dow, on rats and rabbits exposed to 100 and 300 ppm EDC, has been completed and a final report will be issued shortly.

5. A one generation reproduction study in rats, also being conducted at Dow, is in progress, and will be completed in 1979.

The MCA will provide final reports on all the above studies to OSHA as soon as they are available. It is obvious that the results of these studies will significantly add to the data base on EDC and should be appropriately considered in arriving at a regulatory position on EDC.

To place the results of the Maltoni and NCI studies in perspective, additional toxicity studies are being undertaken to elucidate the effects of differing routes of administration of EDC on its metabolism and mechanisms of potential toxicity. We plan to have the results of this research available within the year, and believe that OSHA should await its outcome before proposing further restrictive regulation of EDC.

We are concerned about the feasibility of meeting an unreasonably low ceiling level for EDC, such as the 2 ppm 15-minute ceiling recently recommended by NIOSH. Our experience for semi-volatile organic materials such as EDC indicates that 15-minute ceiling concentrations will generally exceed the 10-hour TWA level by a factor of 10 to 20. We urge that any consideration of a ceiling value in addition to a TWA permissible exposure level involve careful cost/effectiveness analysis.

The remainder of our response is devoted toward the specific information requested in the Federal Register notice. Because of the intervening holidays during the comment period when many key resource personnel were unavailable, we have been unable to complete our data for submission at this time. However, our conversations with personnel in the Health Standards Office of OSHA have assured us that pertinent information will be accepted for a reasonable time beyond February 5, and we plan to have the remainder of our data submitted within the next 4 to 6 weeks.

Enclosed are the following:

Attachment A -
Spencer, H. C., et. al, Vapor Toxicity of Ethylene Dichloride Determined by Experiments on Laboratory Animals, A.M.A. Archives of Industrial Hygiene and Occupational Medicine, November 1951, Volume 4, pp. 482-493.

Attachment B -
Our material safety data sheet for EDC, which lists the properties, hazards, and reactivity of the material, appropriate handling precautions, first aid measures, and spill, leak, and disposal procedures.

Attachment C -
An outline of the sampling and analytical procedures used by Dow to measure concentrations of EDC in the workplace. The method used is essentially that recommended by NIOSH, with some minor modifications.

Attachment D -
Our medical surveillance program for workers with potential exposure to EDC.

Attachment E -
A table of end uses for EDC, along with estimates of the relative volumes of EDC consumed in each.

We expect that our data and comments will be given due consideration and will aid in arriving at a reasonable and appropriate regulatory decision by the agency.

Very truly yours,

C. C. Kazmierski

C. C. Kazmierski
Inorganic Chemicals Department
2020 Dow Center
(517) 636-0184

cah

ATTACHMENT A

Vapor Toxicity of Ethlyene Dichloride Determined by Experiments on Laboratory Animals

H. C. SPENCER, Ph.D.
V. K. ROWE, M.S.
E. M. ADAMS, Ph.D.
D. D. McCOLLISTER, B.S.
AND
D. D. IRISH, Ph.D.
MIDLAND, MICH.

Reprinted, with additions, from the A. M. A. Archives of Industrial Hygiene and Occupational Medicine, November 1951, Vol. 4, pp. 482-493

COPYRIGHT, 1951, BY
AMERICAN MEDICAL ASSOCIATION
535 NORTH DEARBORN STREET
CHICAGO 10, ILL.

Printed and Published in the United States of America

Reprinted, with additions, from the A. M. A. Archives of Industrial Hygiene and Occupational Medicine, November 1951, Vol. 4, pp. 482-493

Copyright, 1951, by American Medical Association

VAPOR TOXICITY OF ETHYLENE DICHLORIDE DETERMINED BY EXPERIMENTS ON LABORATORY ANIMALS

H. C. SPENCER, Ph.D.
V. K. ROWE, M.S.
E. M. ADAMS, Ph.D.
D. D. McCOLLISTER, B.S.
AND
D. D. IRISH, Ph.D.
MIDLAND, MICH.

ETHYLENE dichloride (1,2-dichloroethane) is widely used as a constituent of fumigants, as a commercial solvent, and as a chemical intermediate.

The early pharmacological and toxicological literature has been reviewed by von Oettingen [1] and by Heppel and associates [2]; both acute [3] and chronic [2e] toxicity studies have been reported.

The present experimental work was carried out as a part of a comparative study of the toxicity of vapors of the four chlorinated hydrocarbons: ethylene dichloride, trichloroethylene, tetrachloroethylene, and carbon tetrachloride. These studies were undertaken so that the health problems associated with the use of these materials could be more fully evaluated.

In this comparative study considerable emphasis was placed on quantitative measures of acute toxicity (for the rat) in terms of both capacity to kill and capacity to cause injury (nonfatal). It has been felt that acute toxicity is as important for

---

From the Biochemical Research Department, The Dow Chemical Company.

A summary of this work was presented at the Eleventh Annual Meeting of the American Industrial Hygiene Association, in Chicago, April 27, 1950.

1. von Oettingen, W. F.: The Halogenated Hydrocarbons: Their Toxicity and Potential Dangers, J. Indust. Hyg. & Toxicol. 19:349-448, 1937.

2. (*a*) Heppel, L. A.; Neal, P. A.; Endicott, K. M., and Porterfield, V. T.: Toxicology of Dichloroethane: I. Effect on the Cornea, Arch. Ophth. 32:391-394 (Nov.) 1944. (*b*) Heppel, L. A.; Neal, P. A.; Daft, F. S.; Endicott, K. M.; Orr, M. L., and Porterfield, V. T.: Toxicology of 1,2-Dichloroethane: II. Influence of Dietary Factors on the Toxicity of Dichloroethane, J. Indust. Hyg. & Toxicol. 27:15-21, 1945. (*c*) Heppel, L. A.; Neal, P. A.; Perrin, T. L.; Endicott, K. M., and Porterfield, V. T.: The Toxicology of 1,2-Dichloroethane: III. Its Acute Toxicity and the Effect of Protective Agents, J. Pharmacol. & Exper. Therap. 84:53-63, 1945. (*d*) Heppel, L. A.; Porterfield, V. T., and Sharpless, N. E.: Toxicology of 1,2-Dichloroethane: IV. Its Detoxication by L-Cystine, DL-Methionine and Certain Other Sulfur Containing Compounds, ibid. 91:385-394, 1947. (*e*) Heppel, L. A.; Neal, P. A.; Perrin, T. L.; Endicott, K. M., and Porterfield, V. T.: The Toxicology of 1,2-Dichloroethane: V. The Effects of Daily Inhalations, J. Indust. Hyg. & Toxicol. 28:113-120, 1946.

3. (*a*) Sayers, R. R.; Yant, W. P.; Waite, C. P., and Patty, F. A.: Acute Response of Guinea Pigs to Vapors of Some New Commercial Organic Compounds: I. Ethylene Dichloride, Pub. Health Rep. 45:225-239, 1930. (*b*) Heppel and others.[2e]

SL 080867

industrial hygiene as is chronic toxicity. Accordingly, more satisfactory means of measuring acute toxicity and of obtaining useful information by comparing the results with measures of chronic toxicity have been explored.

EXPERIMENTAL PROCEDURES

Material Tested.—Ethylene dichloride, $CH_2Cl\text{-}CH_2Cl$, is a colorless liquid of a specific gravity of 1.256 at 20 C. (water 1), with a melting point of — 35.5 C. and a boiling point of 83.5 C. It is soluble in water to the extent of 0.81 gm. per 100 gm. at 20 C. and is freely miscible with alcohol and with ether. Ethylene dichloride is stable at moderate temperatures and burns with difficulty.

The material used in this experimental work consisted of four individual samples of a commercial product, all purified by redistillation. The infrared-absorption spectra of these samples indicated purities of at least 99.7%. The only impurity identified was trichloroethylene.

Source and Feeding of Animals.—The albino rats were raised in this laboratory of stock originally obtained from the Wistar Institute of Anatomy and Biology in 1938. They were maintained on a modified Sherman diet consisting of freshly ground whole wheat (55%), dried whole milk (25%), dried extracted liver (12%), dried brewer's yeast (5%), iodized table salt (2%), and calcium carbonate (1%).

The guinea pigs were of a heterogeneous stock purchased from a commercial breeder. They were fed a commercial rabbit chow [4a] (complete ration), alfalfa hay, and cabbage.

The albino rabbits were a heterogeneous stock raised in this laboratory on the same chow [4a] (complete ration) and alfalfa hay.

The rhesus monkeys were imported animals, kept in the laboratory for several months before use. They were fed a variable diet of a commercial laboratory chow,[4b] peanuts, fruits, and vegetables.

Single Exposures.—A glass-walled chamber of about 160-liter capacity, similar to that previously described,[5] was used. Two large copper tubes (closed with rubber stoppers) were soldered into the monel top of the chamber so that rats could be introduced conveniently after a vapor concentration had been established. A constant air flow was maintained through the chamber, the lowest rate for any experiment being about 15 liters per minute and the highest about 30 liters per minute. The desired vapor concentration was obtained by metering liquid ethylene dichloride at a constant rate into the tube through which air entered the chamber, heat being applied at the point of vaporization as needed to effect complete volatilization. All vapor concentrations with animals in the chamber were checked repeatedly from time to time by combustion analyses; the results averaged better than 90% of the calculated theoretical concentrations of ethylene dichloride.

The rats were introduced in groups of 5 to 12 within a period of 15 seconds and were removed through the chamber door within a similar interval of time at the end of the exposure. It was shown by a continuously recording analyzer that the animals were introduced without appreciable alteration of the vapor concentration.

All the rats were selected on the basis of general appearance and apparent good health, males and females being used in approximately equal numbers. Animals that received single exposures were observed as to their behavior, body weight changes, and time of death. Survivors were observed for two to three weeks, or until it was certain that they had fully recovered from the effects of the exposure as judged by appearance, behavior, and recovery of weight. Special groups of rats, separate from those used to determine the relationships between intensity of exposure and survival, were examined for evidence of organic injury at varying times following the single exposures.

Repeated Seven-Hour Exposures.—A metal chamber of about 450-liter capacity was used for exposures at 200 ppm; and a rectangular galvanized sheet-metal box of about 1,700-liter capacity was used for exposures at 400 and 100 ppm. The concentration of 200 ppm was attained by

4. (*a*) The rabbit chow used was that made by the Ralston Purina Company, St. Louis. (*b*) The laboratory chow used was that made by the same company.

5. Irish, D. D., and Adams, E. M.: Apparatus and Methods for Testing the Toxicity of Vapors, Indust. Med. 9:1-4, 1940.

SL 080868

passing a metered amount of air through a vaporizer containing liquid ethylene dichloride and into the constant air flow entering the chamber. The other concentrations were obtained by metering liquid ethylene dichloride and vaporizing this into the air flow entering the chamber. By means of a continuously recording analyzer, it was shown that in every case the vapor was uniformly held within 10% of the desired concentration of ethylene dichloride.

In the repeated exposure experiments the vapor concentration was established after the animals had been placed in the chamber. This was done by atomizing the required amount of ethylene dichloride into the chamber with thorough mixing of the chamber air by means of fans, and then starting the air flow and the ethylene dichloride feed so as to maintain the concentration.

All of the animals used in these experiments were carefully selected on the basis of general appearance, body weight, and growth during a preliminary period of observation. In each experiment two groups of controls were used, well-matched with the experimental animals in respect to number, age, sex, and body weight. The "unexposed controls" were simply maintained in the animal quarters, while the "air-exposed controls" were exposed repeatedly to room air in a chamber similar to that used for the ethylene dichloride-exposed animals. Routinely, the animals were exposed seven hours daily, five days a week.

Throughout the experimental period each animal was weighed twice a week and observed frequently for general appearance and behavior. Growth curves were drawn for each group, and records were kept of food consumption and mortality. During the course of the experiments, periodic hematological examinations were made on several groups of animals. Failing animals were killed for examination when moribund or nearly so. All survivors were killed and examined for evidence of organic injury on the day following the last exposure.

Examination for Organic Injury.—All of the animals examined for organic injury were fasted overnight, weighed, and then killed by decapitation. The gross appearance of each animal was observed, and the lungs, heart, liver, kidneys, spleen, and testes were weighed. Tissues from these organs were saved for the preparation of hematoxylin-and-eosin-stained sections, and in many instances sections of the following were prepared also: adrenal gland, pancreas, stomach, intestine, bone marrow, urinary bladder, ureter, lymph nodes, muscle, brain, and optic nerve. Frozen sections of the liver and a kidney were stained with Sudan IV and Oil Red O.

In many cases blood was obtained at the time of autopsy for the determination of the following: urea nitrogen[6] and/or total nonprotein nitrogen; serum phosphatase[7]; plasma prothrombin clotting time by a modification of the method of Quick.[8] Likewise, in many cases a portion of the liver was frozen with solid carbon dioxide (dry ice) for subsequent lipid analyses. Total lipid was determined gravimetrically on an alcohol-ether extract; phospholipid was calculated from the total phosphorus content; free and esterified cholesterol were determined by separation as the digitonide and use of the Liebermann-Burchard reaction, and neutral fat was calculated by difference.

Wherever possible, the t-test[9] was used in comparing the mean values obtained on the ethylene dichloride-exposed groups with those of the air-exposed controls or unexposed controls as designated; probability values (P) of less than 0.05 indicated a significant difference.

RESULTS OF SINGLE EXPOSURES OF RATS

Mortality from Single Exposures.—The total number of rats used and the number that died from each exposure are listed in Table 1. From the data at 1,000, 1,500, 3,000 and 12,000 ppm, the exposures producing death in 0.01, 50, and

6. Barker, S. B.: The Direct Determination of Urea in Blood and Urine, J. Biol. Chem. 152:453-463, 1944.

7. Hoffman, W. S.: Photelometric Clinical Chemistry, New York, William Morrow & Co., 1941, p. 138-149.

8. Quick, A. J.; Stanley-Brown, M., and Bancroft, F. W.: Study of the Coagulation Defect in Hemophilia and in Jaundice, Am. J. M. Sc. 190:501-511, 1935.

9. Fisher, R. A.: Statistical Methods for Research Workers, ed. 7, London, Oliver & Boyd, Ltd., 1938.

SL 080869

99.99% of the rats were determined statistically according to the method described by Litchfield and Wilcoxon.[10] These points were plotted on log-log ordinates and the lines *AB*, *XY*, and *CD* (Chart 1) drawn to represent the exposures producing death in essentially all of the rats (L. $D_{99.99}$), 50% (L. D_{50}), and essentially none of the rats (L. $D_{0.01}$), respectively. The average factors for determining 19/20 confidence limits were 1.09 for the L. D_{50} points and 1.45 for the points representing the two extremities.

TABLE 1.—*Mortality of Rats Exposed to Various Concentrations of Ethylene Dichloride for Single Periods*

$CH_2Cl\text{-}CH_2\text{-}Cl$ Concentration		Period of Exposure, Hr.	Total Number of Rats	Number That Died
PPM	Mg./L.			
20,000	81.0	0.1	10	0
		0.2	20	0
		0.3	20	16
		0.4	20	20
		0.6	10	10
12,000	48.6	0.1	10	0
		0.2	41	0
		0.3	52	0
		0.4	41	4
		0.5	54	22
		0.6	42	30
		0.7	43	38
		0.8	31	30
		1.0	22	22
3,000	12.1	0.5	22	0
		0.7	44	1
		1.0	32	1
		1.6	44	1
		2.0	51	6
		3.0	40	24
		4.0	40	38
		5.0	22	22
		6.0	20	20
1,500	6.1	2.0	10	0
		3.0	24	1
		4.0	41	2
		6.0	10	7
		7.0	30	24
		8.0	10	7
1,000	4.0	6.0	32	5
		7.0	31	17
		8.0	32	20
800	3.2	7.0	30	10
600	2.4	5.0	20	0
		7.0	33	3
		8.0	20	4
300	1.2	7.0	20	0

Gross Response.—Ethylene dichloride produced a considerable depression of the central nervous system, sufficient at 22,000 ppm to cause deaths within 0.4 hour. At 12,000 ppm and at lower concentrations this depressant action resulted in varying degrees of "drunkenness" but not unconsciousness or death within the duration of the exposures employed. The inactivity or stupor and the slowness of response to handling observed at vapor concentrations of 3,000 ppm and lower may have been due, in part at least, to toxic injury other than the depression of the central nervous system; the prolonged exposures at these lower concentrations produced appreciable organic injury.

10. Litchfield, J. T., Jr., and Wilcoxon, F.: A Simplified Method of Evaluating Dose-Effect Experiments, J. Pharmacol. & Exper. Therap. 96:99-113, 1949.

SL 080870

Deaths of rats tended to occur at three different time intervals and in such a manner as to suggest three separate toxic actions of fatal degree. At 20,000 ppm deaths occurred in deep anesthesia during the period of exposure, undoubtedly due to depression and paralysis of function of the central nervous system. At all vapor concentrations a large proportion of the rats died rather suddenly and quietly a few hours after being removed from the chamber, showing marked cyanosis, reduced body temperature, stupor or coma, and failing respiration. The character of this response and its sudden development often after apparent full recovery suggest "shock" or cardiovascular collapse. All other deaths occurred over a period of two to seven days with progressive loss of weight and other evidence of toxic effects. These deaths appeared to be the result of injury to the kidney.

Organic Injury.—Special groups of animals were killed and examined for evidence of organic injury at various intervals of time after receiving exposures within

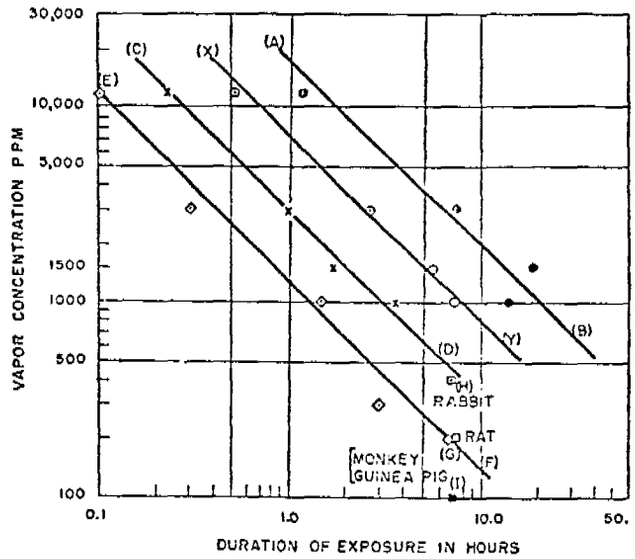


Chart 1.—Vapor toxicity of ethylene dichloride. Line *AB* represents single exposures producing death in 99.99% of the rats; Line *XY*, single exposures producing death in 50%, and Line *CD*, those producing death in 0.01%. Line *EF* represents the most severe single exposures without detectable adverse effect in rats. Point *G* represents the most severe repeated exposures of rats without detectable adverse effect; Point *H*, of rabbits; Point *I*, of monkeys and guinea pigs.

the range bounded by *ABCD* (Chart 1). The evidence of organic injury consisted of the following: decrease in body weight; increase in weights of liver and kidneys; increase in blood urea nitrogen; increase in plasma prothrombin clotting time; decrease in serum phosphatase; increase in liver lipids; histopathological changes in kidney, liver, and adrenal.

The histopathological changes were most pronounced in the kidney and consisted of varying degrees of tubular damage, ranging from slight parenchymatous degeneration of the epithelium to complete necrosis and accompanied by interstitial edema, congestion, and hemorrhage. Animals showing severe renal damage had extremely high concentrations of urea nitrogen in the blood.

In the liver the histopathological changes ranged from slight congestion and slight parenchymatous degeneration to marked hemorrhagic necrosis. Although a few diffusely distributed fat globules were found in some of the severely affected livers, typical "fatty degeneration" was not observed.

The adrenal changes were limited chiefly to congestion and hemorrhage, although in the most severely affected animals there was some parenchymatous degeneration of the adrenal cortex. Only at vapor concentrations above 3,000 ppm was there evidence of pulmonary congestion and edema.

Single Exposures Having No Adverse Effect.—The studies made to determine the nature of the toxic effects caused by the inhalation of ethylene dichloride vapor were extended to permit an estimation of the single exposures of maximum intensity without any evidence of toxic injury. The results of these experiments using groups of four to six female rats are summarized in Table 2. From these data the line *EF* (Chart 1) was located by inspection to represent the most severe single exposures which were without detectable adverse effect on rats.

TABLE 2.—*Single Ethylene Dichloride Exposures Having No Adverse Effect on Female Rats*

CH_2Cl-CH_2Cl Concentration		Hours of Exposure	
PPM	Mg./L.	Without Adverse Effect	With Adverse Effect
12,000	48.6	0.1	0.2
3,000	12.1	0.3	0.5
1,000	4.0	1.5	3.0
300	1.2	3.0	5.5
200	0.8	7.0	...

RESULTS OF REPEATED SEVEN-HOUR EXPOSURES

Concentration: 400 PPM (1.62 Mg. per Liter).—(*a*) Rats: Groups of 15 male and 15 female rats, subjected to repeated seven-hour exposures, experienced severe intoxication. No female rat survived more than 10 exposures in 14 days, and no male rat survived more than 40 exposures in 56 days.

In additional groups of 20 male and 20 female rats each, given two and three exposures, mortality was high (60%). Surviving animals were killed and examined for significant changes as compared with groups of unexposed controls. The experimental animals showed a rapid loss in body weight and a slight increase in the weights of the liver and the kidneys. Histopathological examination of the tissues revealed slight cloudy swelling of the liver with a few large fat vacuoles, principally centrolobular in distribution; no significant changes were observed in the kidneys or other organs examined. Analyses of the livers from the female rats indicated a slight increase in the total lipid content, due chiefly to an increase in neutral fat. There was no significant difference between the values obtained on the experimental and control groups so far as the following determinations on the blood were concerned: urea nitrogen, nonprotein nitrogen, serum phosphatase, and plasma prothrombin clotting time.

(*b*) Guinea Pigs: Groups of eight male and eight female guinea pigs were subjected to repeated seven-hour exposures. These animals experienced such severe intoxication that no male guinea pig survived more than 10 exposures in 14 days and no female survived more than 24 exposures in 32 days.

SL 080872

Additional groups of two male guinea pigs each were killed after 1, 3, 4, and 10 exposures and examined for significant changes as compared with a group of unexposed controls. The experimental animals showed a rapid loss in body weight and an increase in the weights of the liver and the kidneys. Histopathological examination of the tissues revealed slight-to-moderate central fatty degeneration of the liver and slight-to-moderate cloudy swelling of the tubular epithelium of the kidneys; no alterations were observed in the other tissues examined. An average blood nonprotein nitrogen concentration of 91.6 mg. per 100 cc. was obtained on the ethylene dichloride-exposed animals, compared with an average of 61.6 for the controls; the average blood urea nitrogen values were 42.8 and 20.2 mg. per 100

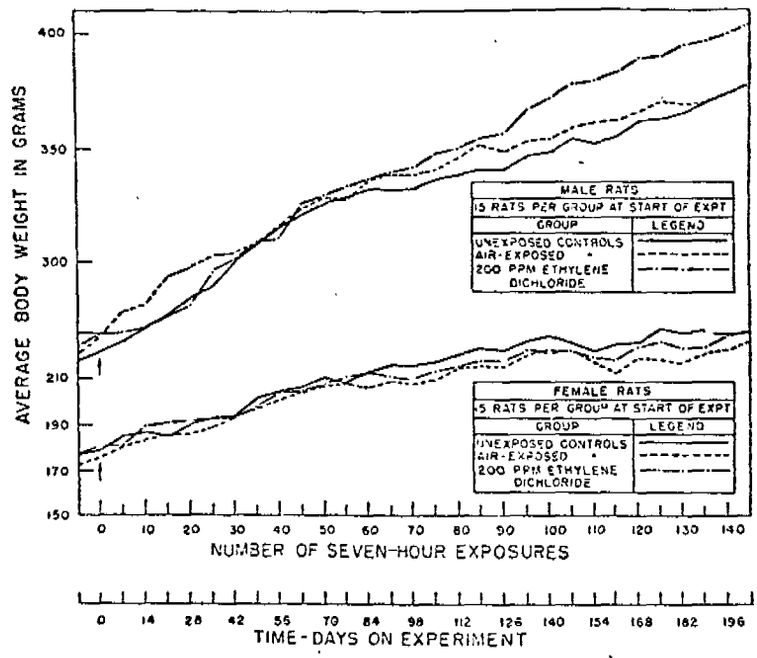


Chart 2.—Growth curves of male and female rats that were repeatedly exposed for seven hours to a 200-ppm ethylene dichloride vapor.

TABLE 3.—*Final Average Body Weights and Organ Weights from Male and Female Rats That Were Exposed to 200 PPM Ethylene Dichloride for 151 Seven-Hour Periods in 212 Days*

Group	Sex	Rats	Av. Body Wt., Gm.	Organ Weights, Gm./100 Gm. Body Wt.					
				Lung	Heart	Liver	Kidneys	Spleen	Testes
Unexposed (controls)	F	11	226	0.75	0.40	2.76	0.76	0.24	....
Air-exposed (controls)	F	12	220	0.71	0.38	2.48	0.68	0.18	....
Exposed to 200 ppm ethylene dichloride	F	11	223	0.71	0.36	2.87	0.80	0.18	....
Unexposed (controls)	M	11	360	0.70	0.36	2.93	0.66	0.16	0.78
Air-exposed (controls)	M	9	358	0.61	0.31	2.23	0.62	0.18	0.69
Exposed to 200 ppm ethylene dichloride	M	9	381	0.65	0.33	2.45	0.68	0.16	0.76

SL 080873

cc., respectively. No appreciable deviation from the contro[illegible]s was evident in the [illegible]e of serum phosphatase or plasma prothrombin clottin[illegible]e.

Rabbits: Two male rabbits and one female rabbit t[illegible]rated 165 exposures in [illegible] days with no evidence of intoxication as judged by g[illegible]l appearance and behavior, mortality, and body weight during the course of t[illegible]periment. At the termination of the experiment no adverse effects were note[illegible] gross and microscopic examination of the tissues, nor from the follo[illegible]g determinations: organ weights, blood nonprotein nitrogen, urea nitrogen, seru[illegible] phosphatase, and plasma prothrombin clotting time.

(*d*) Monkeys: Two male animals that were subjected to repeated seven-hour exposures experienced rapid and severe intoxication. One monkey, killed in a moribund state after eight exposures, showed the following changes as compared with control monkeys: enlargement of the liver with increases of neutral fat and esterified cholesterol content; marked degeneration and vacuolation of liver cells; moderate degeneration of the epithelium of the renal tubules with cast formation and distention of the lumens; and increased plasma prothrombin clotting time. The second monkey, killed after 12 exposures, showed similar changes but of considerably milder degree. Hematological values obtained on these monkeys, either midway in the experiment or terminally, showed no significant changes as compared with values obtained in one to three preexposure examinations.

Concentration: 200 PPM (0.81 Mg. per Liter).—(*a*) Rats: Groups of 15 male and 15 female rats tolerated 151 exposures in 212 days and showed no evidence of adverse effects as judged by general appearance and behavior, growth (Chart 2), mortality, final body and organ weights (Table 3), periodic hematological examination, and gross and microscopic examination of the tissues. Determinations of blood nonprotein nitrogen, urea nitrogen, serum phosphatase and plasma prothrombin clotting time yielded no abnormal results as compared with control values. Analyses of the livers for total lipid content, phospholipid, neutral fat, and free and esterified cholesterol likewise presented no evidence of adverse effect.

(*b*) Guinea Pigs: Groups of eight male and eight female guinea pigs tolerated 180 exposures in 246 days. The experimental groups did not appear to grow as well as the control groups (Chart 3). However, the final body weights (Table 4) were significantly different from the control weights only in the case of the male guinea pigs. Organ weight studies (Table 4) revealed no significant deviations from the control values. The blood urea nitrogen, nonprotein nitrogen, serum phosphatase, and plasma prothrombin clotting time values were normal. Microscopic examination of the tissues revealed no evidence of organic injury except that about half of the guinea pigs examined (both sexes) exhibited slight parenchymatous degeneration of the liver, with a few fat vacuoles diffusely distributed. Liver-lipid analyses indicated on the average a slight increase over the controls in total lipid, phospholipid, neutral fat, and free and esterified cholesterol.

Concentration: 100 PPM (0.405 Mg. per Liter).—(*a*) Rats: Groups of 15 male and 15 female rats were subjected to repeated seven-hour exposures. The male rats tolerated as many as 151 exposures in 211 days and the female rats as many as 142 exposures in 198 days without evidence of adverse effects as judged by general appearance and behavior, mortality, growth, final body and organ weights, periodic hematological examination, and gross and microscopic examination of the tissues.

The values for blood nonprotein nitrogen, urea nitrogen, serum phosphatase, and plasma prothrombin clotting time and the results of studies of the total lipid phospholipid, neutral fat, and free and esterified cholesterol of the liver were all normal.

(*b*) Guinea Pigs: Groups of eight male and eight female guinea pigs were subjected to repeated seven-hour exposures. The males tolerated 121 exposures in 170 days and the females 162 exposures in 226 days and showed no evidence of adverse effects as judged by mortality, growth (Chart 4), final body and organ weights (Table 5), blood nonprotein nitrogen, urea nitrogen, serum phosphatase, plasma prothrombin clotting time, and gross and microscopic examination of the tissues. Analyses for the total lipid, phospholipid, neutral fat, and free and esterified cholesterol of the liver produced only normal results.

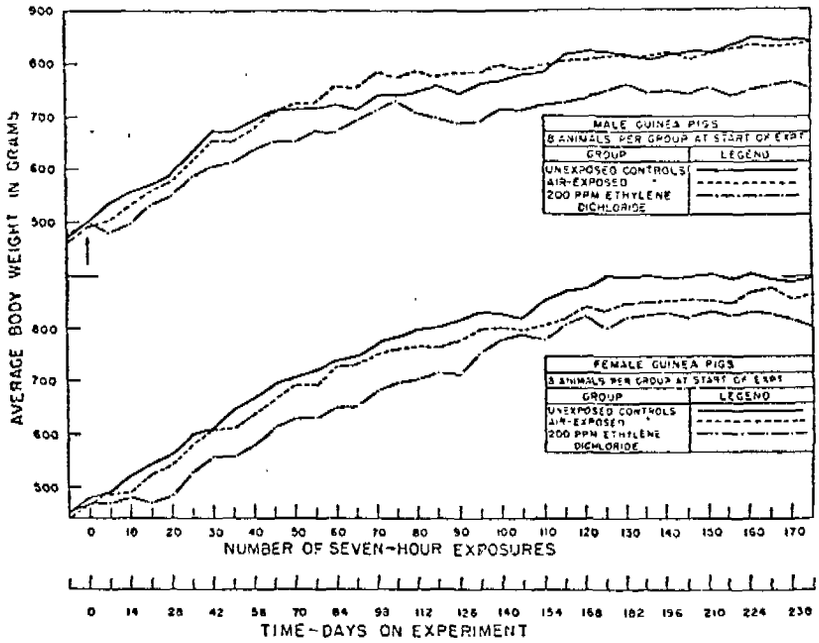


Chart 3.—Growth curves of male and female guinea pigs that were repeatedly exposed for seven hours to a 200-ppm ethylene dichloride vapor.

TABLE 4.—*Final Average Body Weights and Organ Weights from Male and Female Guinea Pigs That Were Exposed to 200 PPM Ethylene Dichloride for 180 Seven-Hour Periods in 248 Days*

Group	Sex	Guinea Pigs	Av. Body Wt., Gm.	Organ Weights, Gm./100 Gm. Body Wt.					
				Lung	Heart	Liver	Kidneys	Spleen	Testes
Unexposed (controls).....	F	7	857	0.77	0 26	3.16	0.52	0 10	....
Air-exposed (controls).....	F	8	836	0.79	0.27	2.99	0.59	0.13	....
Exposed to 200 ppm ethylene dichloride	F	7	759*	0 87	0.27	3.01	0.59	0.12	....
Unexposed (controls).....	M	8	827	0.72	0.29	2.79	0 63	0.13	0.29
Air-exposed (controls).....	M	8	829	0.75	0.28	2.63	0 67	0.13	0.37
Exposed to 200 ppm ethylene dichloride	M	8	700†	0 91	0.32	3.13†	0.71	0.12	0 40

Compared with air-exposed controls:
* $P = > 0.05$.
† $P = 0.001$.

SL 080875

An additional group of 20 female guinea pigs that received 14 exposures in 18 days likewise failed to show any evidence of adverse effects when judged by the same criteria.

(*c*) Rabbits: Two male rabbits and one female rabbit tolerated 178 exposures in 248 days without evidence of adverse effects as judged by general appearance and behavior, growth, final body and organ weights, and gross and microscopic examination of the tissues. Studies of the blood nonprotein nitrogen, urea nitrogen, serum phosphatase and plasma prothrombin clotting time also failed to reveal any evidence of adverse effects.

(*d*) Monkeys: Two male monkeys were subjected to 148 seven-hour exposures in 212 days and exhibited no evidence of adverse effects as judged by general appearance and behavior, periodic hematological examination, growth, final body and organ weights, and gross and microscopic examination of the tissues.

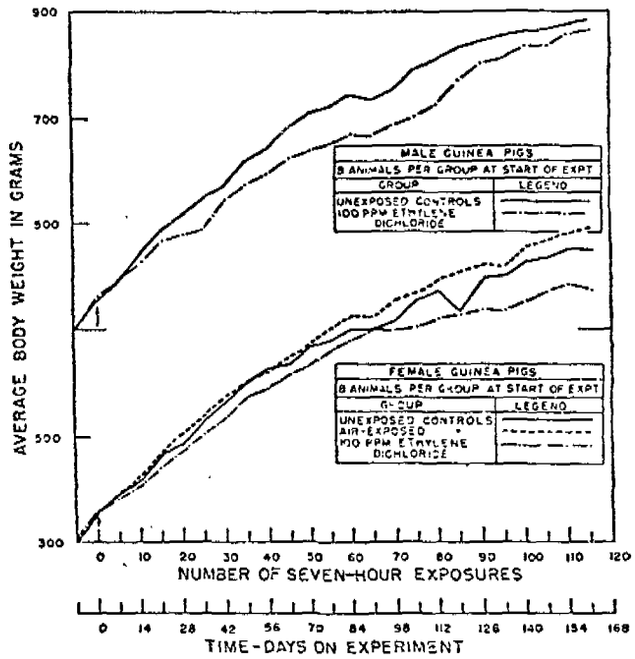


Chart 4.—Growth curves of male and female guinea pigs that were repeatedly exposed for seven hours to a 100-ppm ethylene dichloride vapor.

TABLE 5.—*Average Final Body Weights and Organ Weights from Male and Female Guinea Pigs That Were Exposed to 100 PPM Ethylene Dichloride for as Many as 162 Seven-Hour Periods in 226 Days*

Group	Sex	Guinea Pigs	Av. Body Wt., Gm.	Organ Weights, Gm./100 Gm. Body Wt.					
				Lung	Heart	Liver	Kidneys	Spleen	Testes
Unexposed (controls)	F	7	839	0.93	0.25	2.70	0.59	0.12	....
Air-exposed (controls)	F	8	855	0.78	0.26	2.91	0.59	0.15	....
Exposed to 100 ppm ethylene dichloride	F	5	712*	0.73	0.25	3.27*	0.57	0.12	....
Unexposed (controls)	M	8	881	0.70	0.23	2.67	0.60	0.11	0.15
Exposed to 100 ppm ethylene dichloride	M	7	858*	0.75	0.29	2.91*	0.60	0.11	0.15

Compared with unexposed controls:
* $P = > 0.05$.

SL 080876

SIGNIFICANCE OF RESULTS

Toxicological studies for the purpose of industrial hygiene are intended to yield, first, information on the nature of the toxic effects that may be anticipated in human subjects and, second, quantitative measures of toxicity that may be utilized for the evaluation of intensities of exposure in industry. The observations reported here as well as those published previously [11] reveal a variety of toxic effects, depending primarily on vapor concentration and duration of exposure but also on species and individual susceptibility. A quite meager experience with toxic effects in human subjects [12] has been reported by means of which the results obtained with animals may be checked or verified.

Ethylene dichloride has an unquestioned depressant action on the central nervous system and may be expected to cause in human subjects varying degrees of "drunkenness" and unconsciousness by this action, which may terminate in death. Human experience has verified this depressant action. Vapor concentrations high enough to cause marked central depression also produce irritation within the respiratory system.

The organic injury produced in the liver and the kidneys of various species of animals would certainly be expected in human subjects, and such organic injury has been found in a few cases in which human subjects had ingested liquid ethylene dichloride.

The deaths of rats a few hours after a single exposure, and possibly some of those deaths observed by Heppel and associates,[2c] suggest a rapidly developing functional impairment, such as collapse of the cardiovascular system. Hueper and Smith [12b] reported a human death apparently due to circulatory failure. Actual hemorrhage may be partly responsible for these sudden deaths; certainly, they are not due to the injury of liver and kidney, which may be responsible for delayed deaths.

The outstanding acute toxic effects produced by ethylene dichloride are degeneration, necrosis, and hemorrhage of the liver, the kidneys, and the adrenals. Such effects have occurred in human subjects following ingestion and are always to be anticipated in greater or less degree.

The toxic effects to be expected in human subjects after excessive repeated exposures without obvious acute effects will probably be organic injury of the liver, the kidneys, and the adrenals.

The corneal opacity observed by Heppel and associates [2a] in the dog and the fox were not observed in any of the species employed in this study, nor has it been observed in human subjects.

The quantitative data on acute toxicity represented by the lines *AB*, *XY*, *CD*, and *EF* (Chart 1) appear to be useful measures of the capacity of ethylene dichlo-

11. Lehmann, K. B., and Flury, F.: Toxicology and Hygiene of Technical Solvents, Berlin, Julius Springer, 1938. Heppel and others.[2] Sayers and others.[3a]

12. (*a*) Hamilton, A., and Hardy, H. L.: Industrial Toxicology, New York, Paul B. Hoeber, Inc., 1949. (*b*) Hueper, W. C., and Smith, C.: Fatal Ethylene Dichloride Poisoning, Am. J. M. Sc. **189**:778-784, 1935. (*c*) Hulst, J. P. L.; Steenhauer, A. J., and Kedde, D. L.: Fatal Ethylene Dichloride Poisoning, Nederl. tidjschr. geneesk. 90:406-407, 1946. (*d*) McNally, W. D., and Fostvedt, G.: Ethylene Dichloride Poisoning, Indust. Med. **10**:373-374, 1941. (*e*) Roubal, J.: Časop. lék. česk. 86:1-8, 1947 (Czechoslovakian), abstracted, Chem. Abst. **42**:987e, 1948; Two Cases of Fatal Poisoning with Symmetrical Dichloroethane (CH_2Cl-CH_2Cl) After Oral Intake, Czech. M. J., no. 7, pp. 203-205 (Feb. 21, 1947); abstracted, J. Indust. Hyg. & Toxicol. 30:60, 1948. (*f*) Wirtschafter, Z. T., and Schwartz, E. D.: Acute Ethylene Dichloride Poisoning, ibid. **21**:126-131, 1939.

SL 080877

ride to cause injury and to kill in single exposures. The significance of these data for human subjects could be determined with greater certainty if similar data on other species were available. Other published data on acute ethylene dichloride vapor toxicity [3] show that no other species of laboratory animals is appreciably more susceptible than the rat and that most species are not remarkably more resistant. Almost all species suffered serious or fatal injury from one or but a few seven-hour exposures at less than 1,000 ppm. Accordingly, it would appear reasonable to use the data represented by *CD* and *EF* (Chart 1) for evaluating the toxicological significance of the single exposures for human subjects. These data may not be applicable, however, at high concentrations, greater than about 1,000 ppm, since minimal anesthetic effects may occur in shorter intervals of time than are indicated by *EF*.

The quantitative data on chronic toxicity, represented by points *G*, *H*, and *I* (Chart 1), agree on the whole quite well with data published previously.[2e] It may be concluded with considerable assurance that human subjects will tolerate regularly daily seven-hour exposures to vapor concentrations as high as 100 ppm without injury. This figure has been generally accepted for many years as the threshold limit for industrial exposure.

The outstanding characteristic of these quantitative data is the proximity of *G*, *H*, *I*, *EF*, and *CD* (Chart 1). This suggests that an exposure of excessive degree is very likely to be one that produces acute effects and that chronic intoxication without such acute effects is improbable.

SUMMARY

Rats were exposed to ethylene dichloride vapor for single periods on a varying concentration-time basis. The results were treated statistically and permitted the graphing of lines representing the single exposures causing death in 0.01, 50, and 99.99% of the animals. Additional exposures were made in order to determine the most severe single exposures which were without detectable adverse effects in rats. Typical results were as follows:

LD_{50}—0.53 hour at 12,000 ppm, 2.75 hours at 3,000 ppm, 7.20 hours at 1,000 ppm.
$LD_{0.01}$—0.23 hour at 12,000 ppm, 1.02 hour at 3,000 ppm, 3.70 hours at 1,000 ppm.
No adverse effect—0.1 hour at 12,000 ppm, 0.3 hour at 3,000 ppm, 1.5 hour at 1,000 ppm.

Four animal species were exposed for seven hours daily, five days a week, to ethylene dichloride vapor for six months. Maximum vapor concentrations without adverse effect were as follows: rabbit, 400 ppm; rat, 200 ppm; monkey and guinea pig, 100 ppm.

The toxic effect from single exposures, as observed on experimental animals, consisted of depression of the central nervous system, lung irritation, and organic injury of the liver, the kidneys and the adrenal glands. The significant chronic effect appears to be hepatic and/or renal damage.

It is concluded that for uniform daily exposures of about seven hours' duration there is little probability of any adverse effect on human subjects if the ethylene dichloride concentrations are kept below 100 ppm.

ACKNOWLEDGMENT

The authors are indebted to Mrs. Norabelle T. Williams for the analytical work on lipid constituents of the liver.

Printed and Published in the United States of America

SL 080878

ATTACHMENT B

M A T E R I A L S A F E T Y D A T A S H E E T PAGE: 1

DOW CHEMICAL U.S.A. MIDLAND MICHIGAN 48640 EMERGENCY PHONE: 517-636-4400

EFFECTIVE DATE: 22 DEC 78 PRODUCT CODE: 30457

PRODUCT NAME: ETHYLENE DICHLORIDE MSD: 0166

INGREDIENTS (TYPICAL VALUES-NOT SPECIFICATIONS)	: % :
ETHYLENE DICHLORIDE	: 99.5 :

SECTION 1 PHYSICAL DATA

BOILING POINT: 83.7C (182.7F) : SOL. IN WATER: 0.8 G/100G @ 20C
VAP PRESS: 67.0 MMHG @ 20C : SP. GRAVITY: 1.250 @ 25/25C
VAP DENSITY (AIR=1): 3.42 : % VOLATILE BY VOL: 100
APPEARANCE AND ODOR: COLORLESS, CHLOROFORM-LIKE LIQUID.

SECTION 2 FIRE AND EXPLOSION HAZARD DATA

FLASH POINT: 13C (56F) : FLAMMABLE LIMITS (STP IN AIR)
METHOD USED: TAG CLOSED CUP. : LFL: 6.2% VOL. UFL: 16% VOL.
EXTINGUISHING MEDIA: FOAM, CO2, DRY CHEMICAL. WATER FOG FOR LARGE FIRES.
SPECIAL FIRE FIGHTING EQUIPMENT AND HAZARDS: VAPOR IS HEAVIER THAN AIR AND MAY TRAVEL CONSIDERABLE DISTANCE TO A SOURCE OF IGNITION AND FLASH BACK. WEAR SELF-CONTAINED BREATHING APPARATUS. IGNITION TEMPERATURE 413C (775F). WATER IS LIGHTER THAN EDC AND CAN BE USED AS A BLANKET TO EXTINGUISH FIRE. KEEP VAPORS AWAY FROM POSSIBLE IGNITION SOURCES.

SECTION 3 REACTIVITY DATA

STABILITY: AVOID OPEN FLAMES, WELDING ARCS OR OTHER HIGH TEMPERATURE SOURCES WHICH INDUCE THERMAL DECOMPOSITION. IGNITES IN AIR AT 413C (775F).
INCOMPATIBILITY: AVOID ALKALI, OXIDIZING MATERIAL, AMINES.
HAZARDOUS DECOMPOSITION PRODUCTS: HYDROGEN CHLORIDE.
HAZARDOUS POLYMERIZATION: WILL NOT OCCUR.

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): EXTINGUISH SOURCES OF IGNITION. SMALL SPILLS: MOP UP, WIPE UP OR SOAK UP IMMEDIATELY. REMOVE TO OUT OF DOORS. LARGE SPILLS: CONTAIN LIQUID;

(CONTINUED ON PAGE 2)
(R) INDICATES A REGISTERED OR TRADEMARK NAME OF THE DOW CHEMICAL COMPANY

SECTION 4 SPILL, LEAK, AND DISPOSAL PROCEDURES (CONTINUED)

ACTION TO TAKE FOR SPILLS (USE APPROPRIATE SAFETY EQUIPMENT): (CONTINUED)
TRANSFER TO CLOSED METAL CONTAINERS.

DISPOSAL METHOD: SEND SOLVENT TO A RECLAIMER OR INCINERATE IN EQUIPMENT EQUIPPED WITH AN HCL SCRUBBER ACCORDING TO LOCAL, STATE, AND FEDERAL REGULATIONS. CONTACT THE DOW CHEMICAL COMPANY FOR ADDITIONAL HELP. REFER TO CHEMICAL SAFETY DATA SHEET SD-18, MANUFACTURING CHEMISTS ASSOCIATION, 1825 CONNECTICUT AVENUE, N.W., WASHINGTON, D.C. 20009.

SECTION 5 HEALTH HAZARD DATA

INGESTION: MODERATE SINGLE DOSE ORAL TOXICITY; LD50 RATS 680 MG/KG. MAY BE HARMFUL AND IRRITATING IF INGESTED.

EYE CONTACT: PAIN, MODERATE IRRITATION, AND POSSIBLY TRANSIENT CORNEAL INJURY.

SKIN CONTACT: PROLONGED CONTACT - SOME IRRITATION. IF CONFINED TO THE SKIN, MAY CAUSE A BURN.

SKIN ABSORPTION: LD50 2800 MG/KG RABBIT. TOXICITY IS LOW , BUT MAY BE ABSORBED IN TOXIC AMOUNTS IF CONTACT IS PROLONGED OR EXCESSIVE.

INHALATION: MAY BE IRRITATING AND MAY CAUSE CENTRAL NERVOUS SYSTEM DEPRESSION. OSHA GUIDE AND ACGIH TLV 50 PPM.

EFFECTS OF OVEREXPOSURE: REPEATED PROLONGED EXPOSURE MAY CAUSE LIVER INJURY, CENTRAL NERVOUS SYSTEM DEPRESSION, NAUSEA, DIZZINESS, DRUNKENNESS. NCI STUDY INDICATES THIS MATERIAL IS AN ANIMAL CARCINOGEN VIA GAVAGE STUDIES AT THE MAX. TOLERATED DOSE (MTD) AND 1/2 MTD IN RATS AND MICE; MALTONI INHALATION STUDY UP TO 150 PPM IN RATS AND MICE SHOWS NO CARCINOGENICITY.

SECTION 6 FIRST AID--NOTE TO PHYSICIAN

FIRST AID PROCEDURES:

EYES: IRRIGATE WITH FLOWING WATER IMMEDIATELY AND CONTINUOUSLY FOR FIFTEEN MINUTES. REFER TO MEDICAL PERSONNEL.

SKIN: IN CASE OF CONTACT, IMMEDIATELY FLUSH SKIN WITH PLENTY OF WATER FOR AT LEAST 15 MINUTES WHILE REMOVING CONTAMINATED CLOTHING. CALL A PHYSICIAN. WASH CLOTHING BEFORE REUSE.

INHALATION: REMOVE TO FRESH AIR IF EFFECTS OCCUR. CALL PHYSICIAN AND/OR TRANSPORT TO MEDICAL FACILITY. IF RESPIRATION STOPS, GIVE MOUTH-TO-MOUTH RESUSCITATION.

INGESTION: IF SWALLOWED, INDUCE VOMITING IMMEDIATELY BY GIVING TWO GLASSES OF WATER AND STICKING FINGER DOWN THROAT. CALL A PHYSICIAN. (NEVER GIVE ANYTHING BY MOUTH TO AN UNCONSCIOUS PERSON).

NOTE TO PHYSICIAN:

(CONTINUED ON PAGE 3)
(R) INDICATES A REGISTERED OR TRADEMARK NAME OF THE DOW CHEMICAL COMPANY

DOW CHEMICAL U.S.A. MIDLAND MICHIGAN 48640 EMERGENCY PHONE: 517-636-4400

EFFECTIVE DATE: 22 DEC 78 PRODUCT CODE: 30457
PRODUCT (CONT'D): ETHYLENE DICHLORIDE MSD: 0166

SECTION 6 FIRST AID--NOTE TO PHYSICIAN (CONTINUED)

NOTE TO PHYSICIAN: (CONTINUED)

EYES: MAY CAUSE CORNEAL INJURY OR BURN. STAIN FOR EVIDENCE OF CORNEAL INJURY. IF CORNEA IS BURNED, INSTILL ANTIBIOTIC STEROID PREPARATION FREQUENTLY. CONSULT OPHTHALMOLOGIST.

SKIN: MAY CAUSE MODERATE IRRITATION. CHRONIC EXPOSURE MAY CAUSE DEFATTING TYPE OF DERMATITIS. TREAT AS ANY CONTACT DERMATITIS.

RESPIRATORY: ANESTHETIC OR NARCOTIC EFFECT MAY OCCUR. GOOD WARNING PROPERTIES. ADMINISTER OXYGEN IF AVAILABLE. BRONCHODILATORS, EXPECTORANTS, AND ANTITUSSIVES MAY BE OF HELP.

ORAL: HIGHLY TOXIC. MAY CAUSE CHEMICAL PNEUMONIA IF ASPIRATED INTO LUNGS. DANGER OF CHEMICAL PNEUMONIA MUST BE WEIGHED AGAINST TOXICITY WHEN CONSIDERING EMPTYING THE STOMACH. IF LAVAGE IS PERFORMED SUGGEST ENDOTRACHEAL AND/OR ESOPHAGOSCOPIC CONTROL.

SYSTEMIC: MAY CAUSE KIDNEY DAMAGE. MAY CAUSE LIVER DAMAGE. MAY CAUSE ADRENAL DAMAGE. MAY CAUSE DRUNKENESS. MAY CAUSE NAUSEA OR VOMITING. MAY INCREASE MYOCARDIAL IRRITABILITY. AVOID EPINEPHRINE OR SIMILAR ACTING DRUGS IF AT ALL POSSIBLE. ALCOHOL CONSUMED BEFORE AND AFTER EXPOSURE MAY INCREASE INJURY. CONSULT STANDARD LITERATURE. NCI STUDY INDICATES IT IS AN ANIMAL CARCINOGEN.

SECTION 7 SPECIAL HANDLING INFORMATION

VENTILATION: RECOMMEND CONTROL OF VAPORS TO SUGGESTED GUIDE.

RESPIRATORY PROTECTION: NIOSH APPROVED RESPIRATORY PROTECTION REQUIRED IN ABSENCE OF PROPER ENVIRONMENTAL CONTROL. FOR EMERGENCIES, A SELF-CONTAINED BREATHING APPARATUS OR A FULL-FACE RESPIRATOR AS APPROVED BY NIOSH IS RECOMMENDED.

PROTECTIVE CLOTHING: CLEAN BODY COVERING CLOTHING. IN ADDITION, RUBBER GLOVES, BOOTS, APRON DEPENDING UPON THE EXTENT AND SEVERITY OF EXPOSURE LIKELY.

EYE PROTECTION: SAFETY GLASSES WITHOUT SIDE SHIELDS. WASHING FACILITIES NEAR WORK AREA.

SECTION 8 SPECIAL PRECAUTIONS AND ADDITIONAL INFORMATION

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE: KEEP DRY TO MAINTAIN QUALITY AND REDUCE CORROSION. BULK QUANTITIES SHOULD BE PADDED WITH NITROGEN. AVOID EYE AND SKIN CONTACT AND THE BREATHING OF VAPORS.

ADDITIONAL INFORMATION: ----

LAST PAGE

(R) INDICATES A REGISTERED OR TRADEMARK NAME OF THE DOW CHEMICAL COMPANY

THE INFORMATION HEREIN IS GIVEN IN GOOD FAITH, BUT NO WARRANTY, EXPRESSED OR IMPLIED, IS MADE.

ATTACHMENT C

DOW CHEMICAL U.S.A.

MIDLAND, MICHIGAN 48640

January 8, 1979

AIR SAMPLING AND ANALYSIS OF 1,2-DICHLOROETHANE (EDC) USING ACTIVATED CARBON ADSORPTION, CARBON DISULFIDE DESORPTION AND GAS CHROMATOGRAPHY WITH FLAME IONIZATION DETECTION

The following air sampling and analytical parameters are being followed to minimize the migration and displacement of EDC from the activated carbon collection media and to maximize the collection and analytical efficiency.

Sample Collection (Activated Carbon Adsorption)

For collecting personal air samples, small battery operated pumps are used with air drawn through a commercially available 1 gram PCB (Pittsburgh Coconut Base) 12X30 mesh activated carbon tube at a flow rate of 150 mL/min. The total air volume in a 4 hour work day is 36 Liters. Short term area or excursion air samples are obtained using a 1 gram tube and an air flow rate of 500 mL/min. Total air volumes do not exceed 5 Liters.

Sample Preparation (Carbon Disulfide Desorption)

The following procedure has proved satisfactory in the desorption of EDC from activated carbon.

[1] Carbon disulfide (10 mL) is cooled to dry ice temperature.

[2] The carbon granules are slowly added to the cold CS_2.

[3] The sample is agitated for at least 30 min on a mechanical shaker.

Standard Preparation

Standards of EDC are routinely prepared by injecting a measured volume of EDC into a known volume of CS_2 with a 10 µL syringe.

SL 080882

Sample Analysis

Analysis is performed by gas chromatography/flame ionization detection. The following gas chromatographic conditions are employed.

Column:	10'x1/8" 20% Carbowax 20M + 2% KOH on 80/100 Supelcoport
Temperatures:	Column: 100°C (isothermal) Detector: 300°C
Detection:	FID @ 1024 to 2
Injection:	2 µL on column
Gas Flows:	Nitrogen: 30 mL/min Hydrogen: 30 mL/min Air: 240 mL/min

Recovery Efficiency

Known concentrations, or "spikes", of EDC are prepared and submitted with each set of field samples. Recoveries average 90±5%. Several techniques have been used.

[1] Use a microLiter syringe to inject a known amount of EDC directly into a 100 Liter Saran bag and then aerate the known mixture from the bag onto the 1 gram activated carbon tube at the same air flow rate and total air sample volume as field samples.

[2] A known amount of EDC has been injected into a U-tube through which air is swept. An activated carbon tube is attached to the downstream side of the U-tube to adsorb the chemical as it evaporates.

[3] A known amount of EDC has been injected directly on the charcoal bed.

[4] Phase equilibrium recoveries have been determined.

[5] A known concentration of EDC in nitrogen in a cylinder has been flow controlled through 1 gram commercial charcoal tubes.

Again, the carbon tube and air flows used were the same as those used in obtaining field samples. In addition to EDC, other contaminants known to be present in the work environment were added to the cylinder for determining recovery efficiencies.

No humidity work has been done.

ATTACHMENT D

The following tests are done on workers with potential exposure to EDC:

A) Preemployment and

B) Periodically

Every two years on those over age 40 and every four years on those under age 40:

- History and Physical Exam
- Pulmonary Function ($FVC+FEV_1$)
- ECG
- Chest X-Ray
- Tonometry (over age 40)
- Audiogram
- Laboratory Work:
  - CBC
  - Urinalysis
  - Stools for Occult Blood (over age 40)
  - GGTP
  - SGOT
  - SGPT
  - Alkaline Phosphatase
  - Blood Sugar
  - BUN
  - Cholesterol
  - Total Protein
  - A/G Ratio
  - Uric Acid
  - Bilirubin
  - Serum Protein Electrophoresis (one time only)
  - Alpha 1 Antitrypsin (if alpha 1 globulin is low)

C) Annually - Laboratory work as listed above on everyone.

REF/ns
1/16/79

SL 080884

ATTACHMENT E

U.S. ETHYLENE DICHLORIDE END USES

USE	VOLUME, AS % OF TOTAL
Intermediate for:	
Vinyl Chloride	80 +
Trichloroethylene	2
1,1,1-Trichloroethane	4
Vinylidene Chloride	2
Perchloroethylene	3
Ethylene Diamines	2
Lead Scavenger	2
Export	4
Miscellaneous (includes other chemical intermediates, extraction solvent, reaction/carrier solvent, polysulfide rubber production, cleaning solvent, grain fumigant, adhesives, paint and coating diluent, manufacture of polycarbonate resins)	1

FORM LG-4878

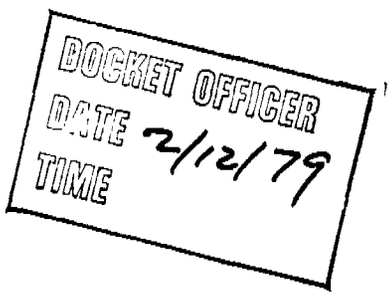
10

E. I. DU PONT DE NEMOURS & COMPANY
INCORPORATED
WILMINGTON, DELAWARE 19898

LEGAL DEPARTMENT

February 5, 1979

Docket Officer
Docket No. H-079
Room S6212
U.S. Department of Labor
Occupational Safety &
Health Administration
Third Street and Constitution
Avenue, N.W.
Washington, D.C. 20210



Sir:

Occupational Exposure to 1,2-Dichloroethane

The attached statement is submitted on behalf of E. I. du Pont de Nemours and Company (Du Pont) in response to OSHA's request for information on the above subject published at 43 Fed. Reg. 56910. We request that our statement be made part of the record on occupational exposure to 1,2-dichloroethane.

For reasons more fully stated in our attached comments, it is our position that:

- No need for an emergency temporary standard has been shown. NIOSH's 1978 recommendation is based solely on a study in which animals were force fed, a route of exposure not found in workplaces. Other current experiments based on dermal and inhalation exposure routes have shown no unusual tumorogenic effects.

- A standard on occupational exposure to 1,2-dichloroethane should contain an exemption for antiknock compounds and fuels which contain these compounds. Due to the presence of lead in the antiknock compounds, employee exposure is closely limited.

- The use of air purifying respirators may be appropriate at workplace exposures of less than 50 ppm. Initial studies have shown these less cumbersome respirators may be an effective means of protecting employees.

SL 080886

We appreciate this opportunity to participate in the hearing record. If you have any questions, please feel free to contact me at (302) 774-9036.

Very truly yours,

B. Anne Gwynn

B. Anne Gwynn
Attorney
Environment Division

AG:kes

Attachments

SL 080887

DU PONT'S RESPONSE TO OSHA'S REQUEST FOR INFORMATION ON OCCUPATIONAL EXPOSURE TO 1,2-DICHLOROETHANE (EDC)

In 43 Fed. Reg. 56910, OSHA requested information on the following items:

(1) Metabolism, including intermediate as well as final metabolites.

(2) Toxicity, tumorigenicity, carcinogenicity, teratogenicity and/or mutagenicity, including the effects of potential co-factors as related to each of these.

(3) Human epidemiology (employee populations and those otherwise exposed).

(4) Appropriate medical surveillance procedures.

(5) Appropriate respiratory protection.

(6) Uses and production technologies.

(7) Employee exposures (actual or potential) in each use and production facility, including: (a) the levels and specific conditions of such exposures, (b) the numbers of employees involved in each exposure situation.

(8) Technological and economic feasibility of reducing employee exposure.

(9) Economic and technological feasibility of complying with a complete 1,2-dichloroethane standard at the lowest level of exposure feasible.

(10) Analytical and sampling methods used and evidence of their precision and accuracy.

(11) Whether issuance of an Emergency Temporary Standard is appropriate.

Items 1 - 3

Du Pont's Haskell Laboratory has not performed any toxicological or epidemiological studies on 1,2-dichloroethane (EDC). However, an initial literature search on the chemical was made in 1975 and updated in recent months. Summaries of the data are attached as Exhibits A and B.

No adverse health effects known to be attributable to exposure to EDC have been observed in Du Pont employees.

Item 4

Extensive medical surveillance should only be required at exposure levels for which there is a reasonable possibility of harmful health effects. Such surveillance should include an annual physical consisting of completion of a health history questionnaire, an examination by or under the supervision of a physician, a posterior-anterior chest x-ray, a urine evaluation for albumin and sugar and blood, hematology to include hemoglobin, hematocrit and white blood count, blood chemistry to include glucose, BUN, SGOT, alkaline phosphatase, creatinine, LDH and bilirubin.

Item 5

NIOSH stated in its Revised Recommended Standard, DHEW (NIOSH) Publication No. 78-211, that only supplied-air or self-contained respirators should be used. While we agree that these respirators should be required for employee exposures above 50 ppm, we believe that the use of air purifying respirators may be appropriate at lower concentrations.

Studies performed by G. O. Nelson and C. A. Harder[1] and subsequent studies performed by Nelson and A. Nicholas Correia[2] show that organic vapor cartridges with charcoal sorbent can absorb EDC at airborne concentrations of 50 ppm for greater than eight hours. If further experimentation verifies appropriate cartridge service life under workplace conditions, use of air purifying respirators, which are less expensive and less burdensome to wear, should be permitted.

Item 6

Du Pont does not manufacture EDC but purchases it for use as a component of Motor Fuel Antiknock Compound (MFAC). MFAC is prepared by blending EDC with tetraethyl lead and/or tetramethyl lead and other components. The compound is sold to oil refiners who blend it with motor fuels.

Item 7

MFAC is produced at Du Pont's Chambers Works at Deepwater, New Jersey, Antioch Works at Antioch, California, and Beaumont Works at Beaumont, Texas.

---

[1] Am. Ind. Hyg. Assoc. J., July, 1974, p. 391, Attached as Exhibit C.

[2] Am. Ind. Hyg. Assoc. J., September, 1976, p. 514, Attached as Exhibit D.

At Chambers Works, EDC is received by ship, tank truck and tank car; the other two locations receive it in tank cars. EDC is pumped into storage tanks from which it is transferred to blending tanks and the blended product pumped to storage tanks. The entire system is closed.

Potential workplace exposure exists when connecting and disconnecting unloading lines from the carrier, during tank gaging and during sampling at various points in the operation. The numbers of employees potentially exposed to EDC at each location including operators, laboratorians, mechanics and supervisors, are:

Chambers Works	104
Beaumont Works	23
Antioch Works	69

Data from personnel monitoring performed from 1975 to the present show the following workplace concentrations:

Chambers Works	Average 8-hr. TWA	Maximum 8-hr. TWA
EDC Handling	0.5ppm	2.2ppm
Finished Product Handling	0.02ppm	0.18ppm
Beaumont		
EDC Handling	0.1ppm	0.5ppm
Finished Product Handling	0.05ppm	0.14ppm
Antioch		
Finished Product Handling		0.01ppm

During carrier connect-disconnect operations, sampling and tank gaging, short-term exposures reach a maximum of 25 ppm. Employees performing these functions wear respirators and impervious gloves.

Item 8

As shown from the monitoring data noted in our response to Item 7, a closed system protects employees during the blending and storage of antiknock compounds. Further reduction of employee exposures is unnecessary.

The unloading, sampling and gaging operations involve only infrequent, intermittent exposures. Exposures of this type should be lowered through the use of personal protective equipment, not through the installation of expensive engineering controls.

Item 9

Du Pont can presently comply with the current OSHA permissible exposure limit of 50 ppm, the ACGIH intended change of 10 ppm, and the 1976 NIOSH proposal of 5 ppm (10hr work day).

We cannot comment on the economic and technological feasibility of complianc with a standard at the lowest level of exposure feasible as we do not know what OSHA considers this level to be. We feel that the permissible exposure chosen should be that level which protects employees against adverse health effects of the chemical. We do not feel that employers should be forced to needlessly expend resources to lower exposure beyond a safe level.

Item 10

We have successfully used the NIOSH Method P&CAM 127 (Organic Solvents in Air) to monitor airborne EDC at the concentrations encountered in our operations. Further study is necessary to determine the precision and accuracy over a range of EDC concentrations.

Item 11

As there is already an OSHA permissible exposure limit in effect for 1,2-dichloroethane and no adverse health effects have been observed at that level, we perceive no "grave danger" to employees and believe that the promulgation of an emergency temporary standard is unwarranted. Any standard proposal should follow the prescribed Section 6(b) standard development process.

If a new permanent standard is promulgated, we recommended that OSHA adopt a permissible exposure level of 10 ppm, the level recommended by the American Conference of Governmental Industrial Hygienists in its Notice of Intended Changes for 1978 TLV's. The ACGIH level is based on recent European occupational experience showing chronic effects resulting in neurologic changes, gastrointestinal problems, and liver and kidney impairment at levels greater than 75 ppm and absent at concentrations lower than 25 ppm.[3] The 1978 NIOSH recommended level of 1 ppm is based solely on a National Cancer Institute carcinogenic study in which rats and mice were fed EDC in corn oil by gastric intubation, an atypical route for industrial exposure. Recent studies which assess the carcinogenic potential of EDC by the most probably routes of industrial exposure - inhalation and dermal do not show any unusual tumorogenic effects. "In an ethylene dichloride inhalation study being conducted in Italy by Dr. C. Maltoni, animals were exposed to ethylene dichloride for 2 years and observed until the end of their natural lives. (Exposure levels in this study are 0, 5, 10, 50, and 150 ppm). No evidence of any exceptional tumors in rats or mice have been found following 100 weeks of exposure (6). Also, Dr. B. M. Goldschmidt has informed NIOSH of bioassays of 1,2-dichloroethane being conducted at the New York University Institute of Environmental Medicine. Groups of 30 female mice received skin applications of 1,2-dichloroethane for more than one year. None of the animals developed skin tumors, and autopsies did not reveal any unexpected internal lesions or tumors (7)."[4]

[3] Criteria for Recommended Standard . . . Occupational Exposure to Ethylene Dichloride HEW Pub. No. (NIOSH) 76-139 (1976).

[4] NIOSH Current Intelligence Bulletin 25. DHEW (NIOSH) Pub. No. 78-149.

Additional Comments

An EDC standard should contain exemptions for products such as antiknock compounds, which contain mixtures of EDC and tetramethyl and/or tetraethyl lead, and for fuels which contain these antiknock compounds.

The manufacture and handling of antiknock compounds is very closely controlled because of the toxicity of the lead compound components. Limiting work place exposure to these lead compounds automatically controls the release of EDC to a safe level.

If the airborne lead concentration in the workplace is maintained at the current OSHA permissible level of 0.075 mg/m^3, the maximum concentrations of EDC which can be present at various temperatures are:

Temperature (°C)	Calculated EDC Concentration (ppm)
10	3.0
20	2.0
25	2.0
30	1.0

As all of the EDC concentrations are well below the 1978 ACGIH recommended level of 10 ppm as well as NIOSH's 1976 recommendation of 5 ppm, these antiknock compounds should be exempted from an EDC standard.

We also request that OSHA exempt mixtures of motor fuels containing EDC from all aspects of any potential EDC regulation. While we do not have direct measurements of workplace concentrations of EDC in the handling of gasoline containing EDC at a gasoline service station, we have measured the concentration of ethylene dibromide (EDB), another component of leaded gasoline, to which a person would be exposed in a service station environment. The concentration of ethylene dibromide (EDB) as detected by a personal air sampler, averaged over 2 hours, was less than 0.1 ppb. A grab sample taken at the vehicle filler pipe showed a maximum concentration of 1-2 ppb. Details of these measurements are given in Exhibit E.

Current leaded gasolines contain 2.0g of lead/gal., 1.0g of EDC/gal. (0.03% by weight) and approximately 1.0g of EDB/gal Based on the measured values of 0.1 ppb of EDB, the workplace concentration of EDC under these same conditions would be 0.5 ppb as measured by the personal monitors with a maximum of 4-8 ppb as measured by the 5-minute grab sample at the vehicle filler pipe.

EXHIBIT A

LITERATURE SEARCH*
1,2-DICHLOROETHANE
(ETHYLENE DICHLORIDE, EDC)

I. ACUTE TOXICITY

A. Oral

a) Values

human	LD_{LO}**	845 mg/kg	(1)
	LD_{100}	56 ml	(3)
rats	LD_{50}	680 mg/kg	(1)
	LD_{50}	680-770 mg/kg	(3)
	LD_{50}	770 mg/kg (670-890)	(4)
mice	LD_{LO}	600 mg/kg	(1)
	LD_{50}	910 mg/kg	(3)
dogs	LD_{LO}	2,000 mg/kg	(1)
	LD_{100}	2,500 mg/kg	(3)
rabbits	LD_{50}	910 mg/kg	(3)

Isomer unspecified:

dog	LD_{50}	1.3 ml/kg	(2)
	LD_{100}	1.9 ml/kg	(2)
guinea pig	LD_{50}	0.6 ml/kg	(2)
	LD_{100}	1.2 ml/kg	(2)
rabbits	LD_{50}	0.8 ml/kg	(2)
	LD_{100}	1.6 ml/kg	(2)
rats			
young	LD_{50}	1,135 $\pm$ 78 mg/kg	(12)
	LD_{100}	2,000 mg/kg	(12)
adult	LD_{50}	625 $\pm$ 50 mg/kg	(12)
	LD_{100}	1,500 mg/kg	(12)
senile	LD_{50}	560 $\pm$ 38 mg/kg	(12)
	LD_{100}	1000 mg/kg	(12)

* Literature Search done 11/25/74.
** Specific gravity 1,1-Dichloroethane = 1.776
1,2-Dichloroethane = 1.256
LD_{LO} = lowest lethal dose
LD_{100} = lethal dose to 100% of test animals
LD_{50} = lethal dose to 50% of test animals

A. Oral (Continued)

mice			
young	LD_{50}	1,308 ± 79 mg/kg	(12)
	LD_{100}	3,000 mg/kg	(12)
adult	LD_{50}	1,120 ± 192 mg/kg	(12)
	LD_{100}	2,500 mg/kg	(12)
senile	LD_{50}	725 ± 38 mg/kg	(12)
	LD_{100}	1,500 mg/kg	(12)

b) Effects

Isomer unspecified:

rats 1-2 ml/kg death at 10-16 hours
Results: bradycardia, bradypnea, total atrioventricular block, cessation of respiration, due to "action on the central nervous system and in particular the respiratory centers." (28)

rats 1.0 ml/kg
rabbits 0.5 ml/kg
Results:
- 24-72 hours: "reversible dystrophic changes in the liver"
- 4-5 days: decrease in fat content of hepatocytes, appearance of cells with 2-3 nuclei
- 6-8 days: necrotic foci disappeared (31)

rats 0.7 ml/kg
Results: decreased rate of oxidative phosphorylation in liver mitochondra (32)

rabbits 1.2 ml/kg
Results: marked increase in fibrinogen content of the blood, acceleration of clotting reaction (41)

rabbits 0.9 - 1.7 ml/kg
Results: toxic pulmonary edema, "accompanied by a series of changes in the blood." (42)

B. Skin

a) Absorption

rabbit	LD_{50}	3890 mg/kg	(1)
	LD_{50}	3.89 ml/kg (3.40-4.46)	(4)
	LD_{50}	2,800 mg/kg	(3)

B. Skin (Continued)

Isomer unspecified:

rabbits 10 mg/l in air
Results: decreases respiration and glycolysis, and cytochromic oxidase in red blood cells, caused a dec[illegible] in activity of serum enzymes, i[illegible]g cholinesterase, affects membrane permeability of renal cells. (29)

b) Irritation

rabbits Score 2* - "trace of capillary injection" (4)

C. Eye

rabbit Score 3* (4)

dog corneal opacity (16)

D. Injection

a) Subcutaneous

rats	LD_{50}	500 mg/kg	(1)
	LD_{50}	1,000 mg/kg	(3)
mice	LD_{LO}	380 mg/kg	(1)
rabbits	LD_{LO}	1,200 mg/kg	(1)
	LD_{100}	1,600 mg/kg	(3)

b) Intraperitoneal

rats	LD_{50}	600 mg/kg	(1)
mice	LD_{LO}	250 mg/kg	(1)
	LD_{50}	470 mg/kg	(6)

c) Intravenous

dog	LD_{LO}	175 mg/kg	(1)
	LD_{100}	175 mg/kg	(3)
	LD_{100}	0.25 ml/kg	(5)
	LD_0	0.125 ml/kg	(5)
mice	0.075 ml/kg	10% increase in urine protein	(34)
	0.2 ml/kg	30% increase in urine protein	(34)
	0.4 ml/kg	56% increase in urine protein	(34)

* Skin irritation scores run from 0 (no effect) to 10 (necrosis)
Eye irritation scores run from 0 (no effect) to 20

E. Inhalation

1 mg/l = 247 ppm and 1 ppm = 4.05 mg/m^3 at 25°C, 760 mm Hg

a) Values

humans	TC_{LO}			4,000 ppm (1)
rats	LC_{LO}	4 hours		1,000 ppm (1)
	LC_{50}			1,000 ppm (3)
	maximum time survived		12 min.	20,000 ppm (8,10)
			1 hour	3,000 ppm (8,10)
			7 hours	300 ppm (8,10)
	no effect times		6 min.	12,000 ppm (8,10)
			1.5 hours	1,000 ppm (8,10)
			7 hours	200 ppm (8,10)
mice	LC_{100}			9,000 ppm (3)
rabbits	LC_{LO}	7 hours		3,000 ppm (1)
	LC_{LO}	unspecified		1,000 ppm (7)
guinea pigs	LC_{LO}	2 hours		9,000 mg/m^3 (1)
	LC_{100}			3,000 ppm (3)
pigs	LC	7 hours		3,000 ppm (1)
rats	LC_{50}	0.53 hours		12,000 ppm (8)
	LC_{50}	2.75 hours		3,000 ppm (8)
	LC_{50}	7.20 hours		1,000 ppm (8)
	LC 0.01*	0.23 hours		12,000 ppm (8)
	LC 0.01	1.02 hours		3,000 ppm (8)
	LC 0.01	3.70 hours		1,000 ppm (8)
no effect level		0.1 hours		12,000 ppm (8)
		0.3 hours		3,000 ppm (8)
		1.5 hours		1,000 ppm (8)
lethal dose		"few minutes"		150,000 ppm (9)
deep narcosis		30 minutes		12,000 ppm (9)
slight symptoms		8 hours		1,000 ppm (9)

* TC_{LO} = lowest toxic concentration
LC_{LO} = lowest lethal concentration
LC_{50} = concentration lethal to 50% of test animals
LC_{100} = concentration lethal to 100% of test animals
$LC_{0.01}$ = concentration lethal to 0.01% of test animals

b) Effects

rats, guinea pigs, rabbits, monkeys 100-400 ppm 7 hours
Results: "depression of the central nervous system, lung irritation, and organic injury of the liver, the kidneys, and the adrenal glands." (8)

rabbits 300 ppm time unspecified
Results: no significant changes in the blood and spinal marrow, with the exception of "toxic granulation in granulocytes of about 20%." (24)

rabbits levels and time unspecified
Results: liver damage, kidney lesions, and "less marked degenerative signs in other organs." (25)

Isomer unspecified:

rats 10 mg/l 4 hours
Results: decrease in cholinesterase activity
serum: 37-43% decrease
plasma: 23% decrease
brain: 16.4% decrease
spinal cord tissues: 16.7% decrease
liver: 27.8% decrease
pancreas: 20.3% decrease
heart: 29% decrease
pylorus: 31.2% decrease (33)

II. CHRONIC TOXICITY

A. Oral

cows 100 ppm 22 days
500ppm, 10 days then 1000 ppm, 12 days
Results: no loss of appetite, no decrease in milk production (13). Levels of 1000 ppm produced concentrations of less than 0.25 ppm in the cow's milk (14).

Isomer unspecified:

rats fed maize, sugar beets treated with 0.1-0.5% EDC time unspecified
Results: no change in blood composition or liver function (30)

B. Inhalation

a) Spencer, et. al. (8,15)

400 ppm

rats	up to	40	7 hour exposures
guinea pigs	up to	24	7 hour exposures
	Results:	no survivors, no tumors, increased liver and kidney weights, histological changes in liver and kidney	
rabbits		165	7 hour exposures
	Results:	maximum for no effect	

200 ppm

rats		157	7 hour exposures
	Results:	maximum for no effect	
guinea pigs		180	7 hour exposures
	Results:	histological changes, no tumors	

100 ppm

rats, male		115	7 hour exposures
, female		142	7 hour exposures
guinea pigs, male		121	7 hour exposures
, female		162	7 hour exposures
rabbits		178	7 hour exposures
monkeys		148	7 hour exposures
	Results:	no adverse effect "The significant chronic effect appears to be hepatic and/or renal damage."	(8)

b) Heppel, L. A. et. al. (17)

1000 ppm — 7 hours/day — 5 days/week

guinea pigs	survived 2 exposures	
rats	survived 3-14 exposures	
rabbits	survived 2-64 exposures	
dogs, cats, monkeys	23-55 days	low mortality
Results:	fatty changes in liver	

400 ppm — 7 hours/day — 5 days/week

rats, rabbits, guinea pigs		high mortality
Results:	liver damage	
dogs	survived 177 exposures	

b) Heppel, L. A. et. al. (Continued)

200 ppm

rats	125 exposures	
Results:	greater than normal mortality, mild pulmonary congestion	
guinea pigs	125 exposures	
Results:	greater than normal mortality, histological changes	
rabbits	125 exposures	no effect
monkeys	125 exposures	no effect

100 ppm

rats survived "many" experiments; no lesions
guinea pigs
monkeys

c) rats, guinea pigs, rabbits, cats 6 hour/day 5 days/week
500 ppm toxic to all in 13 weeks
100 ppm tolerated for 17 weeks (19)

d) rabbits levels unspecified "chronic poisoning"
Results: most severe damage in liver, decrease in lipids of leukocytes, kidney degeration and necrosis, deterioration of kidney function. (25)

e) rabbits 0.6 - 0.15 ml/kg/hour
Results: "bradycardia,...cardiac excitability, and a progressive decrease in the blood pressure to death." (23)

f) rabbits 3000 ppm "chronic exposure"
Results: "A direct poisoning effect on the bone marrow is concluded." (24)

Isomer unspecified:

g) rats 5 mg/l 3.5 months
Results: changes which "reflect pathological excitation followed by decreased functional activity of the entire central nervous system." (18)

h) rats .05 - .01 mg/l 3-5 hours/day
Results: changes in conditioned reflexes histological changes in the brain. Both disappeared when removed from exposure. (22)

i) rabbits 2 mg/m^3 3 hours/day 8-10 months
Results: did not affect antibody formation (20)

j) rabbits 100 mg/m^3 3-4 hours/day 7-11 months
Results: depressed antibody formation, changes in liver and kidneys (21)

rabbits 10 mg/m^3 3-4 hours/day 7-11 months
Results: "not toxic" (21)

k) rats 5 mg/m^3 4 hours/day 1-9 months

rats 3 mg/m^4 and 120 mg/m^3 gasoline
4 hours/day 1-9 months
Results: "considerable changes of the estrus cycle and its periodicity," a decrease in total number of cycles, number of leukocytes and phagocytic activity not affected (27)

l) rats 30 mg/m^3 plus 1210 mg/m^3 gasoline vapors
4 hours/day 6 mos. prior to and during pregnancy
Results: "changes in duration of estrus cycle," decrease in fertility, weight, and muscle efficiency of neonates, increased lethality in progeny, no abnormalities in following gerneration (26)

II. ADDITIONAL EFFECTS

A. Mutagenicity

a) wheat seeds 1 ml for 1 day
Results: 0.3% dominant mutations
1.8% recessive mutations (35)

b) Drosophila melanogaster 0.07% 4-8 hours
Results: increased number of recessive mutations and occurrence of non-divergence of X-chromosome. (36)

c) Drosophila melanogaster levels and time unspecified
Results: increased frequency of recessive lethal mutations, no influence on non-divergence of chromosomes in radioresistant organisms (37)

d) Drosophila melanogaster levels unspecified
Results: 1 day treatment: 25-30% mutations, more pronounced in males
1 hour treatment: 2.6% mutations (38)

B. Other organisms

a) Invertebrates in water 0.1 mg/l
maximum concentration for "normal biological activity" (39)

b) maize prolonged storage with EDC in tropics may affect seedling growth (40)

c) 0.455M kills Vibrio (bacteria)
0.065M prevents fermentation of sugar by yeast (5)

Isomer unspecified:

d) marine pinperch TLm* 150-175 mg/l (59)

e) mole crickets 150 ml/m^2
Results: effective in controlling these insects (43,44)

f) spore-forming bacteria, molds 300 g/m^3
Results: no molds developed, spore-forming bacteria developed normally (48)

IV. METABOLISM

a) readily absorbed from the gastro-intestinal tract or the lungs, absorbed to a lesser extent from the skin (10)

b) mice 0.05 - 0.17 g/kg injected intraperitoneally
10-45% expired unchanged
12-15% expired as CO_2
51-73% urine
0-0.6% feces
0.6-1.3% remaining

Major metabolites:
S-carboxymethylcysteine
thiodiacetic acid
chloracetic acid

Minor metabolites:
2-chloroethanol
S,S'-ethylene bis cystein (45)

c) rats route and dose unspecified
Major metabolite in urine:
N-acetyl-S-(β-hydroxyethyl) cysteine
Secondary metabolite:
S-(β-SS-hydroxyethyl) cysteine (46)

*TLm = median threshold limit

V. HUMAN TOXICITY

"Ethylene dichloride is toxic by inhalation, by contact with skin or mucous membranes, or by oral intake. Prolonged excessive, or repeated exposures to the product in any form are hazardous. The signs and symptoms of excessive absorption to be watched are: headache, mental confusion, depression, fatigue, loss of appetitie, nausea, vomiting cough, loss of sense of balance, and visual disturbances. There may also be diarrhea with bloody stools, suppression of urine, swelling of face, jaundice, and blood in the urine." The signs and symptoms of EDC poisoning are the result of injury to the kidneys, adrenal glands, skin, lungs, and to the digestive and nervous system. The clinical picture varies with the type of exposure and the amount of the chemical product which is absorbed, either at one or at repeated times." (54)

A. Oral

Patty (10) states that EDC "does present a problem from oral ingestion," as evidenced by the number of poisoning fatalities (see below). Effects include CNS depression, gastrointestinal irritation, increase in clotting time, and injury to liver, kidneys adrenals, and lungs.

Should an ingestion occur, vomiting should be induced and epsom sales administered. (54)

B. Skin

a) Irritation and sensitization

If held close to the skin EDC can cause severe irritation with moderate edema and necrosis (10). Repeated or prolonged contact "may cause a rough, red, dry skin due to extraction of fatty materials" (10). "In certain rare cases, the dermatitis may be caused by hypersensitivity to ethylene dichloride" (54,55).

Should skin contact occur, remove all contaminated clothing, wash the area well and apply an ointment containing lanolin. (54)

b) Absorption

EDC can be absorbed through the skin, although "it takes quite large doses to cause serious systemic poisoning." (10)

C. Eye

This chemical and its vapors can cause irritation, burning, and lachyrimation. Serious damage can occur if the substance is not removed promptly. Exposed eyes should be washed with water for 15 minutes. (10,54)

D. Inhalation

Symptoms of both actue and chronic vapor poisoning are irritation of the eyes, nose, and throat, headache, mental confusion, dizziness, and vomiting. EDC "has the ability to cause injury to the liver and kidney from eith excessive single or repeated exposures" (56). Borisova reports that concentrations greater than 6 mg/m^3 "cause vasoconstriction, decreasing light-sensation of the eyes, and reflex changes in rate, depth, and rhythm of respiration." (11)

In the event of overexposure to EDC, remove the subject immediately and do not administer adrenalin. (54)

E. Threshold

a) Single Exposures - not more than once a week

7 hours	200	(56)
1 hour	1,000	(56)
0.1 hour	2,000	(56)

b) Repeated Exposures

Threshold Limit Value (ACGIH)	50 ppm (200 mg/m^3)	(1)
Ceiling Value	50 ppm	(56)
	100 ppm	(1)
Peak Value (not more than 5 min. not more than one in 3 hours for an 8 hour day)	200 ppm	(1)
Recommended Russian Threshold	1 pp,	(11)

c) Odor Levels

50 ppm	barely detectable	(10)
100 ppm	not unpleasant	(10)
200 ppm	pronounced, not unpleasant	(10)
17.5 mg/m^3	detected only by those with acute sense of smell	(11)
23.2 mg/m^3	average level of detection	(11)

The odor of EDC is sweetish and can be adapted to at lower levels; therefore, it is "probably not sufficiently striking to be considered a significant warning of hazardous chronic exposure." (10)

F. Poisoning

Several cases of EDC poisoning have been reported in the literature. "The late appearance and non-specificity of the clinical symptoms and signs" is characteristic of such cases, causing one author to warn that "lack of symptoms even several hours after ingestion or inhalation should not be taken as a reassuring sign." (51)

a) 1-1/2 year male ingestion amount unspecified
Symptoms: 9 hours: no change in EEG
19 hours: pathological changes in nervous system observed
24 hours after infusion-diuresis treatment: normalization of EEG

b) 14 year male ingested 15 ml (for intoxication)
Symptoms: 2 hours: headache, staggering, vomiting
6 days: died
Autopsy: liver necrosis and resultant hypoglycemia, increase in clotting time, renal failure, and hypercalcemia. (51)

c) ingestion 2 oz.
Symptoms: 2 hours: nausea, faint
5 hours: dazed
22 hours: cyanosis, death (5)

d) 18 year male ingested 50 g (suicide)
Effects: death at 18 hours, "basically caused by generalized intravascular clotting accompanied by irreversible shock."
Autopsy: "intense necrotic and hemorrhagic enteritis, widespread erosion of the intestinal mucosa and petechial bleeding subendocardially and supercardially in the kidneys and in the bladder epithelium." (52)

e) Poisoning victims isomer, amount, route unspecified
Autopsy: renal failure, swelling and protein dystrophy in tubular epithelium, decrease in glomerular DNA and RNA. (47)

f) Worker treating grains with Granosan (70% EDC, 30% carbon tetrachloride)
Effects: died with "severe lesions in liver and kidneys" (53)

g) Worker inhalation levels unspecified
Effects: fatal, hyperemia and edema of lungs, degenerative changes of kidney, damage to liver and adrenals. (14)

h) 27 workers inhalation
Effects: non-fatal, CNS depression, semiconsciousness, and hepatorenal syndrome. (57)

i) Russian plane factory using EDC
Effects: number of cases of illness, mostly intestinal and nervous disorders, and number of days lost due to illness were 100% greater in departments using EDC than in rest of the plant. (5

j) Russian factory inhalation (isomer unspecified)
Effects: "chronic hepatitis, chronic gastritis, dystrophy of the myocardium, astenovegetative syndrome, vegetative polyneuritis, and allergy." Polyethylene polyamine had synergistic effects with EDC. (55)

RSFERENCES - 1,2-DICHLOROETHANE (ETHYLENE DICHLORIDE, EDC)

1. The Toxic Substances List (1974).
2. Kagramanov, B. G. Azerb. Med. Zh. 49(7):65-8 (1972). In Azerbaijanian, English Summary from Chemical Abstracts (CA78:53578m).
3. World Health Organization Summary (1970):C-0951.
4. Smyth, H. F. et. al. Am. Ind. Hyg. Assn. J. 30(5):470-6 (1969).
5. Von Oettingen, W. F. J. Ind. Hyg. Tox. 19(8):349-436 (1937).
6. Baganz, H. et. al. Arzneimittel-Forsch. 11:902-5 (1961). Summary from Chemical Abstracts (CA56:6309d).
7. The Toxic Substances List (1973).
8. Spencer, H. C. et. al. A.M.A. Arch. Ind. Hyg. Occup. Med. 4:432-93 (1951).
9. MR 13-121.
10. Patty, F. A. Industrial Hygiene and Toxicology, Vol. II (1963), p. 1280-4.
11. Borisova, M. K. Gig. Sanit. 22(3):13-19 (1957). Summary from Chemical Abstracts (CA51:12364f).
12. Savchenko, M. F. Gig. Sanit. 32(3):31-5 (1967). English translation p. 349-54.
13. Sykes, J. F. and A. K. Klein J. Assoc. Offic. Agr. Chemists 40:203-6 (1957). Summary from Chemical Abstracts (CA51:5320d).
14. "Evaluation of the Hazards to Consumers Resulting from the Use of Fumigants in the Protection of Food." FAO (1965).
15. Shubik, P. and J. L. Hartwell Survey of Compounds Which Have Been Tested for Carcinogenic Activity PHS 149 Supplement I (1957), p. 48.
16. Heppel, L. A. et. al. A.M.A. Arch. Opthamol. 32:391 (1944).
17. Heppel, L. A. et. al. J. Ind. Hyg. Tox. 28:113 (1946).
18. Dmietrieva, N. V. et. al. Gig. Sanit. 36(4):20-5 (1971). Summary from Chemical Abstracts (CA75:18022s).
19. Hofmann, H. Th. et. al. Arch. Toxikol. 27(3):248-65 (1971). In German, English summary from Chemical Abstracts (CA75:61562e).
20. Shmuter, L. M. Gig. Sanit. 37(2):36-40 (1972). In Russian, English summary from Chemical Abstracts (CA76:149673y).
21. Navrotskii, V. K. et al. Tr. S'ezda Gig. Ukr. SSR, 8th 1970 (Pub. 1971), 224-6. In Russian, English summary from Chemical Abstracts (CA77:71060v).
22. Tolgskaya, M. S. Gig. Sanit. 27(2):8509 (1962). In Russian, English summary from Chemical Abstracts (CA57:1223f).
23. Loscalzo, B. et. al. Lavoro umano 11:554-66 (1959). Summary from Chemical Abstracts (CA55:26234b).
24. Lioia, N. et. al. Folia. Med. 42:1238-54 (1959). Summary from Chemical Abstracts (CA54:4908f).
25. Lioia, N. et. al. Folia. Med. 42:1400-8, 1524-57 (1959). Summary from Chemical Abstracts (CA54:13433 e,f,g.h).
26. Vozovaya, M. A. Akush. Ginekol. 1973(9):66-8. In Russian, English summary from Chemical Abstracts (CA80:34236y).
27. Vozovaya, M. A. Akush. Ginekol 47(12):65-6 (1971). In Russian, English summary from Chemical Abstracts (CA77:29874p).
28. Saitanov, A. O. et. al. Gig. Tr. Prof. Zabol. 13(7):49-50 (1969). In Russian, English summary from Chemical Abstracts (CA71:121894u and (CA73:107695q).
29. Petrun, N. M. et. al. Farmakol. Toksikol.30(3):356-8 (1967). In Russian, English summary from Chemical Abstracts (CA67:52291y).
30. Vorob'eva, N. M. Vop. Ratsion. Pitan. 1969(5):123-6. In Russian, English summary from Chemical Abstracts (CA73:65416s).

31. Chernukha, F. S. Farmakol. Toksikol. 1973(8):148-50. In Russian, English summary from Chemical Abstracts (CA80:128950d).
32. Natysuk, M. V. et. al. Farmakol. Toksikol. 37(1):92-3 (1974). In Russinan English summary from Chemical Abstracts (CA80:128965n).
33. Slyusar, M. P. Vopr. Gig. Tr. Prof. Zabol. Gornorudn., Khim. i Mashinostroitel. Prom. Sbornik p. 92-100 (1958). In Russian, English summary from Chemical Abstracts (CA53:5506c).
34. Ploa, G. L. and R. E. Larson Tox. Appl. Pharm. 7:37-44 (1965).
35. Kozhanova, N. N. and N. N. Zoz Agrokhimiya 1966(11):123-4. In Russian, English summary from Chemical Abstracts (CA66:8872x).
36. Sakarnis, V. Genetika 5(12):89-95 (1969). In Russian, English summary from Chemical Abstracts (CA72:129677s).
37. Sakarnis, V. Vestn. Leningrad. Univ. Biol. 1970(1):153-6. In Russian, English summary from Chemical Abstracts (CA73:32801k).
38. Rapoport, I. A. Doklady. Akad. Nauk. S.S.S.R. 134:1214-17 (1960). In Russian, English summary from Chemical Abstracts (CA55:8675h).
39. Lobacheva, L. L. Rybnoe. Khoz. 33(7):71-4 (1957). English summary from Chemical Abstracts (CA51:18355e).
40. Caswell, G. H. et. al. Empire J. Exptl. Agr. 26:365-72 (1958). Summary from Chemical Abstracts (CA53:9554i).
41. Kagramanov, B. G. et. al. Uch. Zap. Azerb. Med. Inst. 36:30-31 (1971). English summary from Toxline.
42. Kagramanov. B. G. Azerb. Med. Zh. 47(3):79-81 (1970). In Russian, English summary from Toxline.
43. Vinnichenko, I. F. Tr. Kishinev. Sel'zkokhoz. Inst. 88:90-2 (1972). In Russina, English summary from Chemical Abstracts (CA79:1328).
44. Vinnichenko, I. F. Tr. Kishinev. Sel'skokhoz. Inst. 66:182-91 (1971). In Russian, English summary from Chemical Abstracts (CA79:1304).
45. Yllner, Sven. Acta. Pharmacol. Toxicol. 30(3-4):257-65 (1971). Summary from Chemical Abstracts (CA76:68867n).
46. Alumot et. al. Fate of Pesticides in Env., Gor. (1972), p.495-501.
47. Kamenko, V. M. Vrach. Delo. 1973(11):72-7. In Russian, English summary from Chemical Abstracts (CA80:104584m).
48. Pod'yapol'skaya, O. P. Tr. Vses. Nauchn.-Issled. Inst. Zerna i Produktov ego Pererabotki No. 43:69-93 (1963). English summary from Chemical Abstracts (CA61:7633f).
49. Secchi, G. C. and L. Alessio Epatologia 17(3):279-89 (1971). In Italian, English summary from Chemical Abstracts (CA77:135890a).
50. Hinkel, G. K. et. al. Kinderaerztl. Prax. 37(5):209-16 (1969). In German, English summary from Toxline.
51. Yodaiken, Ralph E. et. al. Arch. Env. Health 26(5):281-4 (1973).
52. Schoenborn, H. et. al. Klin. Wochshr. 48(13):822-4 (1970).
53. Guarino, A. and N. Lioia Folia. Med. 41:676-90 (1958). Engish summary from Chemical Abstracts (CA53:576g).
54. Chemical Safety Data Sheet SD-18 (1947) (C-951).
55. Voshchinina, G. I. et. al. Mater. Konf. Molodykh. Nauch. Rab. Nizhnego Tagila, Med. Sekts., 2nd, p. 18-20 (1969). In Russian, English summary from Chemical Abstracts (CA78:7459a).
56. Torkelson, T. R. et. al. Pest Control 34(7):13-18, 42-50 (1966).
57. Chenoweth, M. B. et. al. Ann. Rev. Pharm. 2:363-98 (1962).
58. Kozik, I. V. Gig. Tr. Prof. Zabol. 1(1):31-8 (1957). In Russian, English summary from Chemical Abstracts (CA51:9974d).
59. McKee, J. E. et. al. Water Quality Criteria 2nd ed. (1963), p.178.

EXHIBIT B

UPDATE ON
LITERATURE SEARCH
ETHYLENE DICHLORIDE

A. Carcinogenic Potential

- 1,2-Dichloroethane was administered by gavage 5 days a week for 78 weeks to groups of 50 male and 50 female rats and mice. Initial dosage levels for the chronic bioassay were selected on the basis of a preliminary subchronic toxicity test. Subsequent dosage adjustments were made during the course of the chronic bioassay. The time-weighted average high and low doses were 95 and 47 mg/kg/day, respectively for rats of both sexes. The high and low time-weighted average doses for the male mice were 195 and 97 mg/kg/day, respectively, and 299 and 149 mg/kg/day, respectively, for the female mice.

  For each species, 20 animals of each sex were placed on test as vehicle controls. These animals were gavaged with corn oil at the same times that dosed animals were gavaged with the 1,2-dichloroethane mixtures. Twenty animals of each sex were placed on test as untreated controls for each species. These animals were not intubated.

  A statistically significant positive association between dosage and the incidence of squamous-cell carcinomas of the forestomach and hemangiosarcomas of the circulatory system occurred in the male rats, but not in the females. There was also a significantly increased incidence of adenocarcinomas of the mammary gland in female rats.

  The incidence of mammary adenocarcinomas in female mice were statistically significant. There was a statistically significant positive association between chemical administration and the combined incidences of endometrial stromal polyps and endometrail stromal sarcomas in female mice. The incidence of alveolar/bronchiolar adenomas in both male and female mice was also statistically significant.

Under the conditions of this study, 1,2-dichloroethane was carcinogenic to rats, causing squamous-cell carcinomas of the forestomach, hemangiosarcomas, and subcutaneous fibromas in male rats and causing mammary adenocarcinomas in female rats. This compound was also to be carcinogenic to mice, causing mammary adenocarcinomas and endometrial tumors in female mice, and causing alveolar/bronchiolar adenomas in mice of both sexes (1).

- C. Maltoni in Italy is conducting an inhalation study in rats and mice under the sponsorship of MCA and some European companies. After 100 weeks of exposure at 0, 5, 10, 50 and 150 ppm (90 animals/sex level), Maltoni has found no evidence of any exceptional tumor in rats and mice. Pathological examination and a final report are not expected for a year or more (19).

- Ethylene dichloride was administered intraperitoneally, 3 times a week for 8 weeks to groups of 20 mice. Three dose levels were used 20, 40 and 100 mg/kg. Twenty-four weeks after the first injection, the mice were sacrificed and their lungs examined. The pulmonary adenoma response was not significantly greater than the response of vehicle-treated control mice (20).

- B. L. Van Duuren is conducting a study of the chemical structure, reactivity and carcinogenicity of nine halocarbons, one of which is ethylene dichloride. This study is sponsored by the U.S. National Science Foundation, Division of Advanced Environmental Research and Technology. The work is being done at New York University.

B. Mutagenic Potential

1. Ethylene Dichloride

- Ethylene dichloride was a weak mutagen in the Ames test (2,3,10,18). Activation with a rat liver microsomal system did not increase its mutagenicity.

- It did not preferentially inhibit the growth of DNA polymerase-deficient (pol A_1-) *E. coli* (10).

- 1,2-Dichloroethane had no effect on the chromosome-breaking effect and the influence on satellite association in human lymphocytes though a strong toxic effect was induced (17).

- 1,2-Dichloroethane had no effect on the induction of lysis on E. coli K39(λ) (17).

2. Metabolites of Ethylene Dichloride

- It is metabolized in mammals to chloroacetic acid, probably though chloroethanol and chloroacetaldehyde (3,4,5).

- Chloroacetaldehyde was mutagenic in tests with Salmonella typhimurium strain TA 100 but it had only weak activity in strains TA 1535, TA 98 and TA 1538. Chloroethanol was mutagenic in strain TA 100 in the presence of rat liver microsomes but only weakly active without microsomes. There was a weak reversion of TA 1535 but not of the other strains. Chloroacetic acid was not mutagenic in any of the strains tested (3,9).

- Chloroacetaldehyde showed only feeble genetic activity and chloroethanol was completely inactive in inducing forward mutations in two strains of yeast-Schizosaccharomyces pombe and Saccharomyces cerevisiae (6).

- Chloroacetaldehyde was mutagenic in E. coli (7).

- Chloroacetaldehyde, but not chloroacetic acid, was mutagenic in Salmonealla typhimurium TA 1535. Chloroethanol gave a weak mutagenic response only at high concentrations (8).

C. Teratogenic Potential and Effects on Reproduction

- The reproductive activity of male and female rats was not affected when the rats were fed fumigated mash containing ethylene dichloride residue levels of 250 and 500 ppm for two years (11). This paper does not mention the presence of any tumors but it does report on the effect on growth and various biochemical parameters.

- Reproductive studies were carried out with leghorn chickens during the course of a two-year feeding study. They were fed fumigated mash containing ethylene chloride residue levels of 250 and 500 ppm. The fertility of the hens and cocks and the hatchability of the eggs were not affected (12).

- Exposure of female rats to dichloroethane at 57 mg/m^3 daily for four hours during six months and then during the whole gestation period, produced no general toxic symptoms in the females. It did produce reduced fertility, reduced pup weight at birth and increased stillbirth rate. Also observed were reduced viability of the first generation offspring, and retarded gain in weight, prolonged estrous period and high perinatal mortality among the first generation females. No deviations were noted in the second generation offspring (13,14).

- When inhaled at 500-1000 mg/m^3 four hours daily for one to ten days, it penetrated into the uteri and ovaries of non-pregnant rats. It was detected in the fetuses when inhaled at 1000 mg/m^3 on days 10 through 13 or 10 through 17 of gestation. It was also found in the milk of lactating rats following one four-hour exposure (15).

- Exposure to small concentrations of vapors of dichloroethane (concentration and level not specified in the abstract) had only a temporary effect on the estrous cycle of female rats. When rats were exposed to it until days 17 to 19 of gestation, there was an increase in the death rate of the embryos and a loss of embryos at preimplantation (16).

REFERENCES

1. Unpublished Data, National Cancer Institute (1977).

2. Fishbein, L.; Mutat. Res. 32, 267-308 (1976).

3. McCann, J. et al; Proc. Nat. Acad. Sci. USA 72(8), 3190-93 (1975).

4. Yllner, S.; Acta Pharmacol. Toxicol. 30, 257-65 (1971).

5. Heppel, L. A. and V. T. Porterfield; J. Biol. Chem. 176, 763-69 (1948).

6. Loprieno, N. et al; Cancer Res. 36, 253-57 (1977).

7. Hussain, S. and S. Osterman-Golkar; Chem.-Biol. Interact. 12(3-4) 265-7 (1976).

8. Rannug, V. et al; Chem.-Biol. Interact.; 12(3-4), 251-63 (1976).

9. Ames, B. N. and J. McCann; IN: Screening Tests in Chemical Carcinogenesis; edited by H. Bartsch et al; IARC, No. 12, 493-504 (1976).

10. Brem, H. et al; Cancer Res. 34(10), 2576-9 (1974).

11. Alumot, E. et al; Food Cosmet. Toxicol. 14(2), 105-10 (1976).

REFERENCES (CONTD)

12. Alumot, E. et al; Food Cosmet. Toxicol. 14(2), 105-10 (1976).

13. Vozovaya, M. A.; Gig. Sanit. -(7), 25-8 (1974). (CA 82:11901p).

14. Vozovaya, M. A.; Gig. Tr. Prof. Zabol. -(7), 20-3 (1975). (CA 83:202446z).

15. Vozovaya, M. A. and L. K. Malyarova; Gig. Sanit. -(6), 94-6 (1975). (CA 83:109403y).

16. Vozovaya, M. A.; Gig. Sanit. -(6); 100-2 (1976). (CA 85:73056n).

17. Kristoffersson, U.; Hereditas 78, 319 (1974).

18. Rannug, U. and C. Ramel; J. Tox. Environ. Health 2, 1019-29 (1977).

19. Unpublished Information, C. Maltoni.

20. Theiss, J. C. et al; Cancer Res. 37, 2717-20 (1977).

SL 080911

EXHIBIT C

SL 080912

Respirator Cartridge Efficiency Studies: V. Effect of Solvent Vapor

G. O. NELSON and C. A. HARDER

Lawrence Livermore Laboratory, Livermore, California 94550

We have determined the service lives of organic vapor respirator cartridges for 121 solvent vapors and gases including aromatics, alcohols, acetates, alkanes, ketones, amines, and chlorinated materials. We passed the vapor and air mixtures through the cartridges and monitored the downstream concentration with a flame ionization detector (FID). Monitoring continues until the cartridge is completely saturated. We compared breakthrough times to values calculated from the adsorption isotherm and Mecklenburg equation and obtained reasonable agreement. In general, the activated carbon has greater capacity for the less volatile materials. Also, the higher the boiling point of the solvent, the greater is the weight of solvent adsorbed. Water vapor, in general, decreases the amount of solvent vapor adsorbed, especially of the more volatile solvents and those soluble in water. The effect of concentration on breakthrough time was briefly investigated and found to conform to the basic Freundlich equation.

Introduction

THIS IS THE FIFTH in a series of papers concerning respirator cartridge efficiency. The previous reports have described our program goals,[1] the testing apparatus,[2] development of a mechanical breathing simulator,[3] and a comparison of the effects of steady-state and pulsating flow.[4]

We observed no significant difference in cartridge service life between steady-state and pulsating flow. This conforms to basic adsorption theory; equilibrium between the vapor and adsorbent should be practically instantaneous.[5] We discarded the breathing simulator, therefore, and in all subsequent testing employed steady-state flow.

We also observed that the amount of solvent adsorbed at a given temperature, humidity, and concentration is essentially constant (see Figure 1) and is independent of the flow rate in the range normally associated with human breathing. Since the equilibrium rates are so rapid, the time to reach a predetermined breakthrough is inversely proportional to the flow rate. That is, doubling the flow through the cartridges will halve the effective service life if all the other test parameters remain the same.

The present investigation sought to determine how the cartridge service life varies with the type of solvent vapor adsorbed. We investigated 121 solvent vapors and gases and compared observed breakthrough times with the values calculated from the adsorption isotherm and the Mecklenburg equation. This report, in some respects, represents an

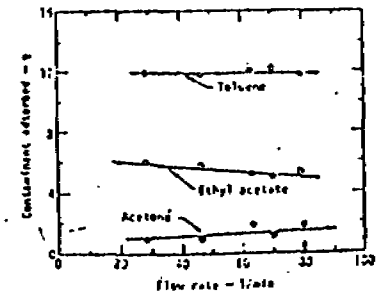


Figure 1. Contaminant adsorbed as a function of flow rate.

This work was performed under the auspices of the United States Atomic Energy Commission.

extension of the investigation by Freedman *et al.*[5]

Our standard test conditions included a solvent concentration of 1000 ppm, 50% relative humidity, and 53.3-liter/min flow, equivalent to a moderately heavy work rate of 839 kg-m/min. The solvents tested included aromatics, alcohols, acetates, alkanes, ketones, amines, and chlorinated materials. Some preliminary investigations on the effect of concentration (125 to 2000 ppm) were also initiated.

Experimental Procedure

The apparatus used to generate and monitor the test concentrations is basically the same as that described in refs. 2 and 4. Several minor changes appear in Figure 2.

The humidifier now consists of a Lucite reservoir with a level switch and solenoid valve assembly to maintain a constant water volume. A 126-watt spot heater on the reservoir bottom controlled by a humidity monitor holds the humidity constant.

A 2-inch plug of glass wool added to the solvent vapor injection port aids in evaporating the solvents, especially those with higher boiling points. Maintaining the block temperature as close to the boiling point as possible avoids decomposing the solvent and plugging the needle. The activated carbon plug downstream further smooths solvent vaporation irregularities.

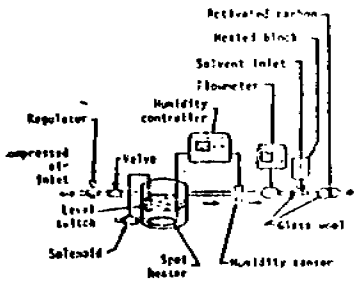


Figure 2. Schematic diagram of humidifier and solvent vaporizer.

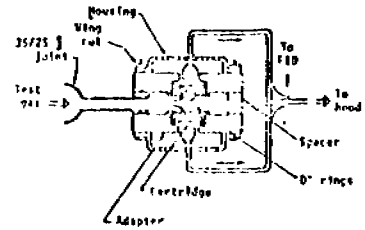


Figure 3. Schematic diagram of dual cartridge holder.

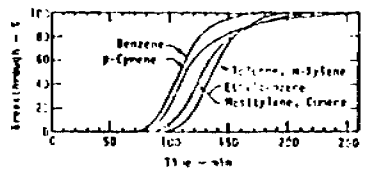


Figure 4. Breakthrough curves for aromatics boiling in the range 80° to 177°C.

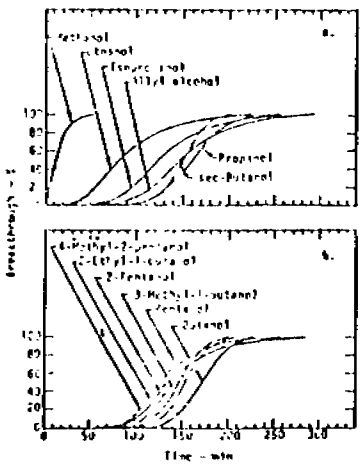


Figure 5. Breakthrough curves for alcohols boiling in the ranges *(a)* 65° to 100°C and *(b)* 118° to 141°C.

The cartridges were vacuum-dried and stored in a cabinet for at least 2 days at 50% relative humidity and 22°C. Two cartridges were tested simultaneously in the parallel configuration shown in Figure 3.

The test gas entered through a 35/25 ground brass socket joint and passed through the cartridges held in individual polyethylene adaptors. Anodized aluminum housings, secured with wing nuts, collected the downstream gases and conducted them to the common sample outlet.

Type I cartridges (see ref. 4 for cartridge

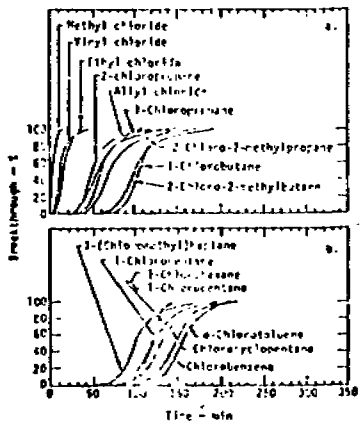


Figure 6. Breakthrough curves for monochlorides boiling in the ranges *(a)* −24° to 86°C and *(b)* 108° to 172°C.

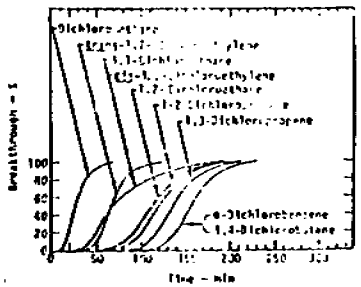


Figure 7. Breakthrough curves for dichlorides boiling in the range 40° to 180°C.

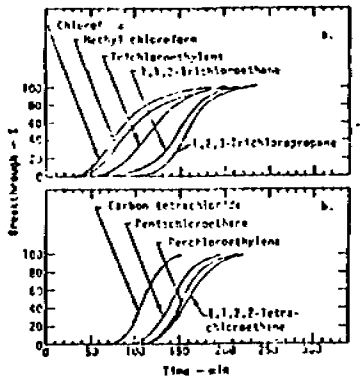


Figure 8. Breakthrough curves for *(a)* trichlorides and *(b)* tetra- and pentachlorides boiling in the ranges 61° to 156°C and 77° to 161°C, respectively.

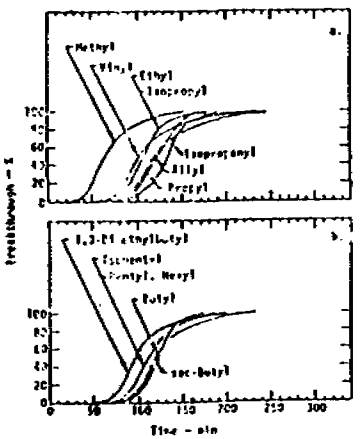


Figure 9. Breakthrough curves for acetates boiling in the ranges *(a)* 57° to 104° and *(b)* 112° to 169°C.

SL 080913

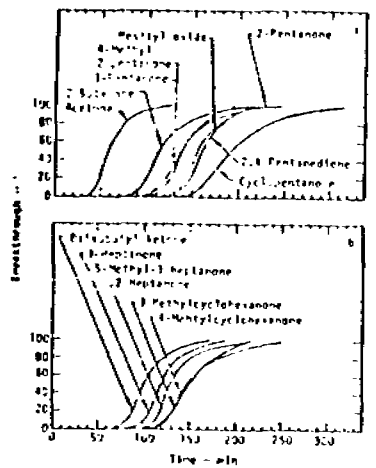


Figure 10. Breakthrough curves for ketones boiling in the ranges *(a)* 56° to 104°C and *(b)* 112° to 169°C.

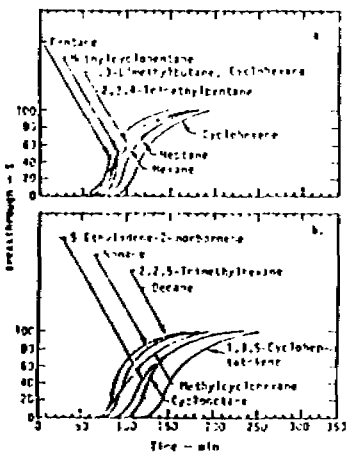


Figure 11. Breakthrough curves for alkanes boiling in the ranges *(a)* 39° to 99°C and *(b)* 101° to 174°C.

characteristics) were tested with aromatics, alcohols, esters, and chlorinated materials; type 2 cartridges were tested with ketones, alkanes, amines, and most miscellaneous compounds.[4]

Results

Effect of Solvent Vapor

Figures 4 through 13 show how the cartridge service life varies when tested with each class of solvent vapor. The percent breakthrough (the ratio of the downstream

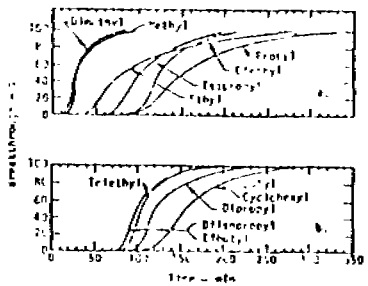


Figure 12. Breakthrough curves for amines boiling in the ranges *(a)* −7° to 56°C and *(b)* 78° to 135°C.

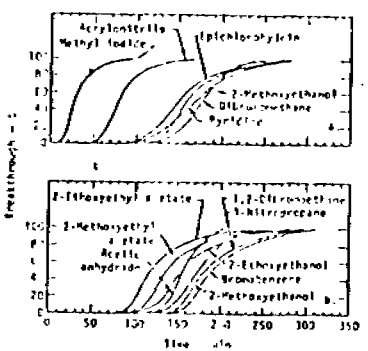


Figure 13. Breakthrough curves for miscellaneous solvents boiling in the ranges *(a)* 42° to 124°C and *(b)* 132° to 156°C.

TABLE I

Solvent	BP (°C)	Vapor pressure at 20°C (Torr)	Diffusion coefficient[a] at 25°C (cm^2/sec)	Volume charcoal (ml)[4]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{50\%}$ (min)	Wt. solvent adsorbed per wt. of carbon at $t_{1\%}$[c] (g/g)	at $t_{10\%}$[d] (g/g)	at $t_{100\%}$[e] (g/g)	Weight vapor adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Aromatics[5]												
Benzene	80.1	75.4	0.0932	146	59.1	73.3	88.4	120	0.214	0.249	0.327	0.335
Toluene	110.6	21.8	0.0849	144	57.5	94.3	114	146	0.334	0.397	0.473	-
Ethyl benzene	136.2	7.08	0.0755	148	59.9	83.7	175	215	0.352	0.432	0.573	0.321
o-Xylene	138.4	6.16	0.0670	148	59.7	96.7	116	193	0.388	0.450	0.536	-
Cumene	152.4	3.35	0.0677	146	60.0	81.2	103	155	0.359	0.447	0.538	0.022
Mesitylene	164.7	1.73	0.0665	147	59.5	85.5	105	140	0.382	0.460	0.565	-
p-Cresol	170.7	1.28	0.0630	148	58.9	75.6	92.9	255	0.394	0.476	0.584	-
Alcohols[5]												
Methanol	64.7	96.8	0.1520	148	55.4	0.2	3.2	47.0	0.0005	0.004	0.018	0.091
Ethanol	78.4	43.6	0.1181	146	55.5	24.0	45.3	207	0.051	0.079	0.168	0.135
Isopropanol	82.3	32.4	0.1015	145	55.7	54.3	81.4	247	0.129	0.188	0.314	0.133
Allyl alcohol	97.0	21.4	0.1021	145	55.4	65.5	105	280	0.152	0.234	0.362	0.117
Propanol	97.1	14.4	0.0995	144	55.7	70.4	111	250	0.168	0.235	0.384	0.065
sec-Butanol	99.5	12.6	0.0891	144	55.8	96.0	121	196	0.281	0.347	0.448	0.050
Butanol	117.7	5.65	0.0841	145	55.5	115	141	255	0.340	0.409	0.512	0.016
2-Pentanol	119.0	4.36	0.0728	147	56.7	66.4	111	277	0.298	0.373	0.517	0.020
3-Methyl-1-butanol	131.2	2.4	0.0706[b]	147	55.0	97.0	121	195	0.344	0.421	0.525	0.047
4-Methyl-2-pentanol	131.8	3.0	0.0653[b]	148	55.7	75.4	96.1	245	0.306	0.382	0.545	0.041
Pentanol	137.9	1.82	0.0716	148	55.0	102	130	206	0.362	0.451	0.552	0.018
2-Ethyl-1-butanol	146.8	1.56	0.0653[b]	150	55.7	76.5	101	257	0.318	0.400	0.582	0.030

SL 080914

TABLE I (Continued)

Solvent	BP (C°)	Vapor pressure at 20°C (Torr)	Diffusion coefficient at 25°C (cm^2/sec)	Volume charcoal (ml)[a]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{25\%}$ (min)	Wt. solvent adsorbed per wt. of carbon at $t_{1\%}$[c] (g/g)	at $t_{10\%}$[d] (g/g)	at $t_{100\%}$[e] (g/g)	Weight water adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Monochlorides[g]												
Methyl chloride	-24.2	3440	0.1140[h]	145	55.7	0.05	0.2	18.6	0.0001	0.001	0.005	0.074
Vinyl chloride	-13.9	2310	0.0995[h]	147	55.7	3.8	6.6	46.3	0.009	0.016	0.038	0.070
Ethyl chloride	12.5	1110	0.0950[h]	148	56.1	5.6	10.7	38.7	0.014	0.026	0.048	0.078
2-Chloropropane	35.2	450	0.0419[h]	148	56.8	26.1	55.3	109	0.069	0.107	0.167	0.018
Allyl chloride	44.5	300	0.0975	141	55.5	30.5	44.6	108	0.093	0.132	0.194	0.040
1-Chloropropane	46.7	277	0.0929[h]	145	55.8	24.5	34.8	141	0.0[illegible]	0.105	0.[illegible]	0.060
2-Chloro-2-methylpropane	50.8	240	0.0737[h]	147	57.0	37.4	52.3	168	0.151	0.185	0.278	0.010
1-Chlorobutane	77.5	80.0	0.0745[h]	145	55.8	72.3	98.1	145	0.265	0.317	0.391	0.008
2-Chloro-2-methylbutane	85.7	60.3	0.0675[h]	148	57.0	56.8	79.3	124	0.243	0.320	0.439	-
1-Chloropentane	108.2	23.8	0.0621[h]	147	56.8	74.7	96.6	137	0.310	0.[illegible]	0.505	-
Chlorocyclopentane	113	-	0.0716	148	55.6	77.5	106	143	0.322	0.429	0.562	0.050
Chlorobenzene	132	9.11	0.0747	146	55.8	107	131	205	0.478	0.574	0.698	-
1-Chlorohexane	134.5	7.15	0.0631[h]	151	55.8	79.3	95.9	189	0.379	0.449	0.591	0.013
o-Chlorotoluene	159.2	2.66	0.0688	146	55.5	102	122	192	0.514	0.605	0.741	0.005
1-Chloroheptane	159.2	2.2	0.0591[h]	150	55.5	81.5	101	145	0.437	0.531	0.625	0.013
3-(Chloromethyl) heptane	172.	-	0.0551[h]	148	55.7	83.4	80.5	183	0.374	0.465	0.614	0.032

TABLE I (Continued)

Solvent	BP (C°)	Vapor pressure at 20°C (Torr)	Diffusion coefficient at 25°C (cm^2/sec)	Volume charcoal (ml)[a]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{25\%}$ (min)	Wt. solvent adsorbed per wt. of carbon at $t_{1\%}$[c] (g/g)	at $t_{10\%}$[d] (g/g)	at $t_{100\%}$[e] (g/g)	Weight water adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Dichlorides[g]												
Dichloromethane	40.2	336	0.1037	142	55.4	10.1	15.2	63.7	0.034	0.052	0.101	0.110
trans-1,2-Dichloroethylene	49	265	0.0825[h]	145	55.7	33.0	50.5	124	0.127	0.167	0.[illegible]	0.055
1,1-Dichloroethane	56.5	156	0.0919	143	55.5	23.3	40.1	225	0.092	0.[illegible]	0.[illegible]	0.034
cis-1,2-Dichloroethylene	53.5	182	0.0823[h]	144	55.3	29.8	42.6	165	0.116	0.160	0.298	0.041
1,2-Dichloroethane	83.5	[illegible]	0.0987	144	55.5	54.0	79.2	166	0.214	0.[illegible]	0.456	0.016
1,2-Dichloropropane	96.4	42.5	0.0774	145	55.8	62.0	90.5	200	0.241	0.[illegible]	0.554	0.034
cis,trans-1,3-Dichloropropene	108	-	0.0703[h]	147	56.7	85.5	110	208	0.319	0.402	0.606	0.036
1,4-Dichlorobutane	162	3.10	0.0604[h]	146	55.6	108	129	215	0.405	0.[illegible]	0.[illegible]	-
o-Dichlorobenzene	180.4	0.36	0.0640[h]	145	57.3	107	132	239	0.618	0.[illegible]	0.[illegible]	-
Trichlorides[g]												
Chloroform	61.2	159.3	0.0886	144	55.6	53.2	72.4	174	0.155	0.[illegible]	0.[illegible]	0.050
Methyl chloroform	74	105	0.0774	144	56.2	68.4	88.9	197	0.212	0.289	0.530	0.036
Trichloroethylene	86.5	58.6	0.0875	145	54.8	55.3	85.0	195	0.293	0.[illegible]	0.[illegible]	0.038
1,1,2-Trichloroethane	113.6	37.5	0.0792	145	56.1	71.8	112	206	0.377	0.[illegible]	0.[illegible]	0.043
1,2,3-Trichloropropane	156	7.1	0.0672[h]	147	56.2	111	152	225	0.643	0.[illegible]	0.[illegible]	-

SL 080915

TABLE I (continued)

Solvent	BP (°C)	Vapor pressure at 20°C (Torr)	Diffusion coefficient at 25°C (cm^2/sec)	Volume charcoal (ml)[a]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{99\%}$ (min)	Wt. solvent adsorbed per wt. of carbon $t_{1\%}$[c] (g/g)	$t_{10\%}$[d] (g/g)	$t_{100\%}$[e] (g/g)	Weight water adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Tetrachlorides[g]												
Carbon tetrachloride	76.8	92.1	0.0826	144	55.4	77.0	90.0	147	0.473	0.545	0.627	
Perchloroethylene	121.2	14.0	0.0797	146	55.7	107	129	209	0.724	0.835	1.01	
1,1,2,2-Tetrachloroethane	145	4.73	0.0722	144	55.3	104	131	216	0.809	0.871	1.07	
Pentachlorides[g]												
Pentachloroethane	161	-	0.0673	145	56.1	121	147	187	0.742	0.914	1.13	
Acetates[g]												
Methyl acetate	57.1	170.2[i]	0.0978	146	55.6	32.8	46.5	143.8	0.097	0.133	0.214	0.073
Vinyl acetate	72.5	91.2	0.0792[h]	148	55.6	59.0	83.1	225	0.168	0.243	0.351	0.006
Ethyl acetate	77.2	74.1	0.0861	145	60.6	66.8	84.7	172	0.215	0.267	0.350	0.006
Isopropyl acetate	87.5	47.5	0.0770	146	55.6	64.5	85.8	166	0.262	0.333	0.453	0.036
Isopropenyl acetate	96	32.9	0.0731[h]	145	57.1	80.6	105	171	0.325	0.409	0.507	
Propyl acetate	101.5	34.3	0.0763	145	55.3	78.8	99.0	164	0.318	0.392	0.507	0.025
Allyl acetate	103.5	-	0.0718[h]	148	56.1	75.8	95.5	245	0.299	0.369	0.517	0.043
sec-Butyl acetate	111.5	-	0.0648	145	55.9	82.0	101	164	0.381	0.456	0.537	-
Butyl acetate	126.1	8.0	0.0672	148	55.0	77.5	96.3	225	0.351	0.443	0.595	0.025
Isopentyl acetate	141.5	3.5	0.0703[h]	148	55.8	70.1	92.5	171	0.365	0.447	0.584	0.020

TABLE I (continued)

Solvent	BP (°C)	Vapor pressure at 20°C (Torr)	Diffusion coefficient at 25°C (cm^2/sec)	Volume charcoal (ml)[a]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{99\%}$ (min)	Wt. solvent adsorbed per wt. of carbon $t_{1\%}$[c] (g/g)	$t_{10\%}$[d] (g/g)	$t_{100\%}$[e] (g/g)	Weight water adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Acetates[g] Cont.												
1,3-Dimethylbutyl acetate	131.2	1	0.0560[h]	149	55.8	60.6	78.0	188	0.326	0.426	0.503	0.025
Pentyl acetate	145.4	2.05	0.0610	149	55.7	72.6	87.3	225	0.373	0.444	0.614	0.014
Hexyl acetate	169	-	0.0567[h]	148	55.5	67.0	85.3	202	0.385	0.440	0.658	-
Ketones[j]												
Acetone	56.2	787	0.1049	146	60.8	37.1	46.0	139	0.078	0.095	0.135	0.309
2-Butanone	79.6	78.6	0.0903	150	66.0	61.0	84.4	230	0.199	0.225	0.295	0.256
2-Pentanone	102.3	36.7	0.0795	150	58.0	104	121	231	0.311	0.392	0.463	0.016
3-Heptanone	102.7	37.3	0.0740[h]	152	58.4	93.5	114	175	0.305	0.365	0.449	0.055
4-Methyl-2-pentanone	117.8	16	0.0697[h]	150	58.1	96.1	111	231	0.307	0.418	0.511	0.067
Mesityl oxide	129.4	7.8	0.0700	149	60.2	122	139	224	0.440	0.495	0.578	-
Cyclopentanone	130.7	-	0.0706[h]	149	64.3	141	161	308	0.408	0.468	0.565	-
2,6-Dimethylheptone	148.4	6.5	0.0622[h]	150	70.6	130	154	214	0.406	0.447	0.527	0.069
3-Heptanone	147.5	-	0.0628[h]	150	58.5	91.0	105	150	0.336	0.351	0.548	0.014
2-Heptanone	151.2	5.8	0.0626[h]	152	61.9	101	114	237	0.412	0.470	0.560	0.005
Cyclohexanone	155.6	5.4	0.0625[h]	150	64.7	126	144	210	0.423	0.477	0.485	0.005
5-Methyl-3-heptanone	156.5	-	0.0584[h]	153	62.9	46.4	59.5	184	0.344	0.442	0.550	0.024

SL 080916

TABLE I (Continued)

Solvent	BP (C°)	Vapor pressure at 20°C (Torr)	Diffusion coefficient at 25°C (cm^2/sec)	Volume charcoal (ml)[a]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{99\%}$ (min)	Wt. solvent adsorbed per wt. of carbon $t_{1\%}$[c] (g/g)	$t_{10\%}$[d] (g/g)	$t_{100\%}$[e] (g/g)	Weight water adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Ketones[i] Cont.												
3-Methyl-cyclohexanone	168	-	0.0669[h]	162	63.5	101	123	216	0.305	0.472	0.595	-
Diisobutyl ketone	169.4	-	0.0454[h]	167	60.4	70.8	85.3	171	0.300	0.437	0.556	0.005
4-Methylcyclo-hexanone	171.5	-	0.0669[h]	172	67.9	111	126	245	0.463	0.520	0.580	0.309
Alkanes[i]												
Pentane	36.1	424	0.0842	166	62.6	60.7	71.3	147	0.155	0.179	0.228	0.020
2,3-Dimethylbutane	58.0	191	0.0689[h]	167	63.5	72.0	81.1	197	0.216	0.241	0.300	0.021
Hexane	68.7	121	0.0732[h]	160	58.0	52.3	64.6	178	0.181	0.220	0.334	0.036
Methylcyclopentane	71.8	110	0.0736[h]	164	66.7	62.2	76.1e	174	0.174	0.202	0.278	0.036
Cyclohexane	80.7	77.5	0.0743[h]	161	59.5	68.7	82.3	179	0.216	0.254	0.337	0.024
Cyclohexane	83.5	70.4	0.0765[h]	153	57.3	85.8	100	193	0.272	0.315	0.401	-
2,2,4-Trimethyl-pentane	96.5	38.6	0.0504[h]	164	57.5	66.3	80.2	174	0.300	0.348	0.440	0.019
Heptane	98.5	35.4	0.0636[h]	160	57.9	76.2	89.8	188	0.299	0.339	0.432	0.018
Methylcyclohexane	100.9	36.2	0.0679[h]	160	57.5	68.5	80.5	191	0.259	0.300	0.440	0.045

TABLE I (Continued)

Solvent	BP (C°)	Vapor pressure at 20°C (Torr)	Diffusion coefficient at 25°C (cm^2/sec)	Volume charcoal (ml)[a]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{99\%}$ (min)	Wt. solvent adsorbed per wt. of carbon $t_{1\%}$[c] (g/g)	$t_{10\%}$[d] (g/g)	$t_{100\%}$[e] (g/g)	Weight water adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Alkanes[i] Cont.												
1,3,5-Cyclo-heptatriene	115.5	-	0.0742[h]	168	63.6	121	137	246	0.389	0.435	0.536	0.003
2,2,5-Trimethyl-hexane	124.5	12.5	0.0559[h]	164	64.2	67.6	80.0	168	0.266	0.310	0.444	0.001
5-Ethylidene-2-norbornene	147.5	4.2	0.0644[h]	163	67.4	86.5	101	221	0.341	0.393	0.526	0.007
Cyclooctane	150	-	0.0620[h]	172	70.3	96.6	113	220	0.345	0.397	0.497	0.027
Nonane	150	3.15	0.0550[h]	165	63.5	76.2	89.3	198	0.340	0.393	0.490	
Decane	174	0.76	0.0530[h]	164	57.7	70.8	81.5	158	0.386	0.439	0.553	0.017
Amines[i]												
Methylamine	-6.7	2160	0.1300[h]	161	58.5	12.4	17.9	91.5	0.015	0.020	0.061	0.150
Dimethylamine	6.7	1285	0.1023[h]	164	70.0	17.1	21.7	94	0.014	0.037	0.060	0.291
Ethylamine	16.6	672	0.1032[h]	161	59.8	40.5	49.7	270	0.068	0.081	0.179	0.268
Isopropylamine	31.5	478	0.0879[h]	160	60.4	65.6	75.8	194	0.142	0.162	0.275	0.136
Propylamine	47.8	247	0.0870[h]	172	65.5	90.0	111	330	0.180	0.217	0.335	0.252
Diethylamine	55.5	188	0.0993	160	62.1	68.0	105	213	0.229	0.269	0.351	0.100
Butylamine	77.5	75	0.0872	162	63.9	110	125	278	0.278	0.312	0.429	0.011
Triethylamine	89.4	46.2	0.0754	160	59.1	81.1	91.0	174	0.307	0.341	0.426	0.032
Dipropylamine	110	18.2	0.0647[h]	170	68.2	93.0	105	226	0.305	0.340	0.439	0.060
Diisopropylamine	110.5	-	0.0647[h]	171	67.0	77.0	87.1	185	0.257	0.288	0.370	0.069

SL 080917

TABLE I (Continued)

Solvent	BP (C°)	Vapor pressure at 25°C (Torr)	Diffusion coefficient at 25°C (cm^2/sec)	Volume charcoal (ml)[a]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{95\%}$ (min)	Wt. solvent adsorbed per wt. of carbon $t_{1\%}$ (g/g)[c]	$t_{10\%}$ (g/g)[d]	$t_{100\%}$ (g/g)[e]	Weight water adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Amines[i] Cont.												
Cyclohexylamine	134	-	0.0664[h]	160	64.3	112	128	279	0.352	0.431	0.564	0.141
Dibutylamine	159	1.1	0.0547[h]	164	64.[illegible]	[illegible]	84.8	146	0.335	0.372	0.480	0.009
Miscellaneous												
Methyl iodide[i]	42.4	336	0.0903[h]	160	53.2	11.6	17.7	4.5	[illegible]	[illegible]	0.137	[illegible]
Acrylonitrile[i]	77.3	87.8	0.1059	160	58.0	49.5	61.1	168	[illegible]	0.121	0.174	0.016
Dibromomethane[i]	98.6	33	0.0836	160	62.8	82	121	279	0.562	0.717	1.06	0.008
Pyridine[i]	115.3	15.4	0.0724[h]	160	64.3	119	134	292	0.321	0.360	0.460	0.076
Epichlorohydrin[g]	116.9	12.5	0.0821[h]	150	56.9	[illegible]	110	[illegible]	0.308	0.357	0.566	0.014
2-Methoxyethanol[g]	124.4	[illegible]	0.0864	148	55.5	116	[illegible]	[illegible]	[illegible]	0.433	0.540	0.096
1,2-Dibromoethane[i]	131.5	8.6	[illegible]	161	61.9	141	165	[illegible]	[illegible]	1.09	1.336	-
1-Nitropropane[i]	131.6	7.7	0.0751[h]	160	63.2	143	164	[illegible]	0.445	0.501	0.618	-
2-Ethoxyethanol[g]	135.5	-	0.0756	148	55.4	77.0	123	243	0.277	0.326	0.393	0.011
Acetic anhydride	139.6	3.7	0.0775[h]	161	61.0	124	138	210	[illegible]	0.306	0.392	0.070

TABLE I (Continued)

Solvent	BP (C°)	Vapor pressure at 25°C (Torr)	Diffusion coefficient at 25°C (cm^2/sec)	Volume charcoal (ml)[a]	Weight charcoal (g)[b]	Experimental breakthrough times $t_{1\%}$ (min)	$t_{10\%}$ (min)	$t_{95\%}$ (min)	Wt. solvent adsorbed per wt. of carbon $t_{1\%}$ (g/g)[c]	$t_{10\%}$ (g/g)[d]	$t_{100\%}$ (g/g)[e]	Weight water adsorbed at $t_{100\%}$ per wt. carbon[f] (g/g)
Miscellaneous Cont.												
2-Methoxyethyl acetate[g]	144.5	3.6	0.0666[h]	150	55.7	95.3	113.2	303	0.435	0.521	0.707	-
Bromobenzene[i]	155	3.0	0.0661[h]	160	[illegible]	142	159	[illegible]	[illegible]	0.910	1.126	-
2-Ethoxyethyl acetate[g]	156.3	2.0	0.0619[h]	148	55.8	79.5	96.7	215	0.417	0.497	[illegible]	0.010

[a] Average volumes for a cartridge pair are 146.3 ± 1.4 ml for the Type 1 and [illegible] ± 4.3 ml for the Type 2.

[b] Average weights for a cartridge pair are 56.[illegible] ± 1.2 g for the Type 1 and 62.2 ± 3.3 g for the Type 2.

[c] Calculated from $W_{1\%} = t_{1\%}$ (VQC/24.1 10^6 W_c).

[d] Estimated from $W_{10\%} = [t_{1\%} + 0.9\ (t_{10\%} - t_{1\%})]$ (VQC)/24.1 10^6 W_c.

[e] See Ref. 4, "Data Processing," calculation of W_s.

[f] Calculated from $W_{H_2O} = W_{total} - W_s$.

[g] Used Type 1 cartridges.

[h] Calculated from Gilliland's equation $D_{25} = [0.0043T^{1.5}(1/M_{air} + 1/M_{vap})^{0.5}]/(V_{air}^{0.33} + V_{vap}^{0.33})^2 P$, where V_{air} is 29.9 ml/mol and V_{vap} is calculated from the LeBas approximation (see Ref. 9).

[i] Used Type 2 cartridges.

SL 080918

to the upstream concentration) for each solvent is shown as a function of time. These figures yield the complete adsorption history from initial breakthrough to total cartridge saturation for each of the solvents and gases tested.

Table I helps summarize the data shown in Figs. 4 through 13. Here solvents are arranged by classes, and within classes by boiling point, with the most volatile compound shown first. The times to reach 1%, 10%, and 99% breakthrough and the respective weights adsorbed are shown for each solvent.

This table shows that, within each class of solvent, the most volatile solvent breaks through first. As the boiling points of the solvents within a class increase, however, the trend eventually reverses. At some point the breakthrough time actually *decreases* with rising solvent boiling points. This occurs for each class of solvent.

Table I also illustrates how the weight of solvent adsorbed varies with the vapor pressure as well as the boiling point. Within each solvent class the weight adsorbed is both an increasing function of the boiling point and a decreasing function of the vapor pressure—the two being interrelated. This is shown to be the case for 1%, 10%, and 100% breakthrough. These data can be used, therefore, to approximate the weight adsorbed of an untested solvent once its class and boiling point or vapor pressure are known.

Table I also gives the diffusion coefficients and the activated carbon weights and volumes needed in the theoretical calculation of the breakthrough times. It also shows the weights of water adsorbed. Note the relatively large amount of water adsorbed in connection with more volatile solvents, especially those that are miscible with water.

Calculation of Breakthrough Times

The ability to predict the cartridge breakthrough mathematically for any solvent that may be encountered would be useful. Initial cartridge breakthrough can be calculated from

$$t_b = \frac{10^4 V_m w W_c}{MQC} \qquad (1)$$

where t_b = initial cartridge breakthrough time (min).

V_m = molar volume at the system temperature and pressure (24.1 liters/mole at 20°C, 760 torr).

w = weight of solvent adsorbed per gram of activated carbon (gm/gm).

W_c = weight of activated carbon (gm).

M = molecular weight of the contaminant (gm/mole).

Q = airflow rate (liters/min)

C = upstream gas concentration (ppm).

All the terms can be measured or calculated except w. The weight of solvent adsorbed is extremely difficult to predict, since it is a complex function of the nature of the adsorbent and solvent vapor. Therefore, equation 1 is useful only if the weight is determined experimentally. Estimations of the breakthrough time can be calculated, however, from the adsorption isotherm and the Mecklenburg equation.

The adsorption isotherm for microporous adsorbents yields the maximum weight of solvent adsorbed at total carbon saturation and can be calculated by

$$w_s = \rho W_0 \exp\left\{\frac{-B}{\beta^2}[\log(p_s/p)]^2\right\} \qquad (2)$$

where w_s = equilibrium static adsorptive capacity per unit weight carbon (gm/gm).

ρ = density of solvent (gm/cm³).

W_0 = total volume of adsorption space (cm³/gm).

B = microporosity constant for the carbon.

T = temperature (°K).

β = affinity coefficient of solvent vapor for the activated carbon.

p_s = saturated vapor pressure (torr) for the solvent at temperature T.

p = equilibrium partial pressure of the solvent vapor (torr).

This adsorption isotherm holds for any microporous adsorbent and is valid only at temperatures below the critical temperature of the vapor. The W_0 and B terms are interrelated and depend only on the nature of the adsorbent. The affinity coefficient β characterizes the adsorption of a given vapor with respect to another vapor selected as a standard. Generally benzene is chosen, its β becomes 1.00 by definition. The affinity coefficient is independent of the temperature and practically independent of the porosity.

The β term can be determined experimentally or approximated by

$$\beta \sim \frac{P}{P_s} \sim \frac{v}{v_s} = \frac{\rho_s M}{M_s \rho} \qquad (3)$$

where v, v_s = molar volume for the unknown and standard solvent (cm/mole).

P, P_s = parachors for the unknown

TABLE II

Cartridge Characteristics and Test Conditions Used for Calculating Weight of Solvent Adsorbed, w_s, from Adsorption Isotherm

Parameter	Cartridge Type 1	Cartridge Type 2
Density, ρ (gm/cm³)	*	*
Maximum adsorption space, W_0 (cm³/gm)	0.65	0.61
Degree of porosity, B	1.0×10^{-6}	0.95×10^{-6}
Temperature, T (°K)	293	293
Affinity coefficient, β	See Tables IV and V	
Saturated vapor pressure, p_s (torr)	See Table I	
Solvent vapor pressure at 1000 ppm, p (torr)	0.76	0.76

*Obtained experimentally from weight and volume measurements.

TABLE III

Cartridge Characteristics and Test Conditions Used for Breakthrough Time Calculations* from Mecklenburg Equation

Parameter	Cartridge Type 1	Cartridge Type 2
Weight of solvent adsorbed (w_s) per weight of activated carbon (gm/gm)	See Table I	
Carbon density, ρc (gm/cm³)	0.375	0.289
Cross-sectional area of carbon, A (cm²)	32.1	39.6
Number of cartridges tested, n	2	2
Flow rate, Q (liters/min)	53.3	53.3
External surface, a_s (cm²/gm)	45	77
Diameter of granule, d (cm)	0.165	0.117
Viscosity of air-vapor stream, η (gm/cm-sec)	1.83×10^{-4}	1.81×10^{-4}
Density of air-vapor stream, ρa (gm/cm³)	1.2×10^{-3}	1.2×10^{-3}
Breakthrough concentration, C_b (ppm)	10	10
Inlet concentration, C_0 (ppm)	1000	1000
Molecular weight, M (gm/mole)	*	*
Void volume, V_v (cm³/gm)	0.42	0.38
Cartridge volume, V (cm³)	70	80
Diffusion coefficient at 25°C, D (cm²/sec)	See Table I	

*At 25°C and 760 torr.

*Obtained from the *Handbook of Chemistry and Physics*.

SL 080919

and standard solvent (calculated from Sugden's equation).

ρ, ρ_s = solvent density for the unknown and standard solvent (gm/cm³)

M, M_s = molecular weights for the unknown and standard solvent (gm/mole).

All the parameters needed to solve the adsorption isotherm are given in Tables I through V. Comparison of the actual experimental values of w_s are also shown in Tables IV and V. Note that the more volatile materials show the greatest deviation from the calculated values. This is due primarily to the preferential adsorption of the water vapor present. In theory, the adsorption isotherm described by equation 2 is valid only for a single vapor in air; it neglects competing adsorption by water or any other vapors. Even by expanding the adsorption isotherm to include multiple vapor systems, it is still difficult to predict to what extent highly polar materials such as

TABLE IV
Comparison of Calculated and Observed Adsorption Capacity of Type 3 Cartridges for Several Solvents[a]

Solvent	Affinity Coefficient, β	Adsorptive Capacity, w_s Observed (gm/gm)	Calculated from Equation 3 (gm/gm)	Deviation from Observed (%)
Benzene	1.00[b]	0.322	0.316	+ 2.5
Toluene	1.31[b]	0.473	0.307	+ 7.2
m-Xylene	1.38[c]	0.336	0.340	+ 0.7
Methanol	0.40[b]	0.038	0.048	+167
Ethanol	0.61[b]	0.168	0.251	+ 49
Propanol	0.84[d]	0.384	0.429	+ 12
n-Butanol	1.02[d]	0.512	0.495	− 3.3
n-Pentanol	1.22[d]	0.552	0.525	− 4.9
Methyl chloride	0.36[b]	0.008	0.016	+100
Ethyl chloride	0.76[b]	0.048	0.129	+169
1-Chloropropane	0.91[c]	0.166	0.253	+ 49
1-Chlorobutane	1.09[c]	0.191	0.426	+ 9.0
Chlorobenzene	1.18[c]	0.362	0.369	+ 1.9
Dichloromethane	0.66[b]	0.101	0.216	+114
1,2-Dichloroethane	0.90[c]	0.436	0.355	+ 22
1,4-Dichlorobutane	1.28[c]	0.255	0.220	− 4.6
o-Dichlorobenzene	1.36[c]	0.931	0.851	− 6.6
Chloroform	0.86[b]	0.415	0.518	+ 25
1,1,2-Trichloroethane	1.08[c]	0.773	0.822	+ 6.3
Carbon tetrachloride	0.96[b]	0.677	0.690	+ 1.9
Perchloroethylene	1.28[c]	1.02	0.965	− 4.5
Methyl acetate	0.85[d]	0.214	0.333	+ 56
Ethyl acetate	1.10[d]	0.350	0.442	+ 26
Propyl acetate	1.30[d]	0.507	0.513	+ 1.2
Butyl acetate	1.45[d]	0.584	0.550	− 5.8
Pentyl acetate	1.61[d]	0.616	0.577	− 6.3

[a] The equilibrium partial pressure, p, at 1000 ppm is 0.76 torr. The saturated vapor pressure, p_s, is taken from Table I.
[b] Experimental values taken from ref. 6.
[c] Calculated from parachors using Sugden's equation.
[d] Calculated from equation 3 using molar volumes.

water will interfere with the normal adsorption processes of organic vapors. Currently there is no satisfactory method of correction for this interference.[6,9]

As was previously mentioned, w_s is the weight adsorbed at 0% of saturation—that is, at 100% breakthrough. Initial breakthrough, however, occurs long before the equilibrium adsorptive capacity is established. Nevertheless, such breakthrough times can be estimated from the Mecklenburg equation once w_s has been determined.

The Mecklenburg equation states that

$$t_b = \frac{w_s \rho_s A n}{QC_0}\left[z + \frac{1}{a_s \rho_c}\left(\frac{aG}{n}\right)^{0.41}\left(\frac{n}{\rho_a D_{12}}\right)^{0.67} \ln(C_0/C_t)\right] \quad (4)$$

where

$$C_0 = \frac{MC_t}{24.1 \times 10^6}$$

$$G = \frac{1000 p_s Q V_s \rho_s}{60.4 n}$$

$$z = V/A$$

$$D_{12} = 0.967 D_{11}$$

and ρ_c = carbon density (gm/cm³).
A = cross-sectional area of the adsorbent bed (cm²).
V = carbon volume (cm³).
n = number of cartridges tested.
C_0 = assault concentration (gm/liter).
z = bed depth (cm).
a_s = specific surface area (cm²/gm).
d = diameter of granule (cm).
G = mass velocity through cartridge (gm/cm²-sec).
n = viscosity of the air-gas stream (gm/cm-sec).
ρ_s = density of air-vapor stream (gm/cm³).
D = diffusion coefficient (cm²/sec).
C_b = breakthrough concentration (ppm).
C_t = assault concentration (ppm).
V_s = void volume (cm³/gm).

Equation 4 is generally useful only for $C_b/C_t < 0.2$—that is, for breakthroughs

TABLE V
Comparison of Calculated and Observed Adsorption Capacity of Type 2 Cartridges for Several Solvents[a]

Solvent	Affinity Coefficient, β	Adsorptive Capacity, w_s Observed (gm/gm)	Calculated from Equation 2 (gm/gm)	Deviation from Observed (%)
Acetone	0.88[b]	0.215	0.236	+9.5
2-Butanone	1.10[b]	0.259	0.360	+39
2-Pentanone	1.19[b]	0.481	0.427	−11
2-Heptanone	1.57[b]	0.540	0.493	−8.8
Pentane	1.08[b]	0.228	0.225	−1.3
Hexane	1.295[b]	0.334	0.349	+4.5
Heptane	1.46[b]	0.432	0.375	−13
Nonane	1.85[d]	0.540	0.484	−11
Decane	2.05[d]	0.553	0.442	−20
Methylamine	0.72[d]	0.041	0.061	+49
Ethylamine	0.91[d]	0.379	0.166	−73
Butylamine	1.29[d]	0.429	0.371	−14
Diethylamine	1.25[d]	0.480	0.466	−2.9

[a] The equilibrium partial pressure, p, at 1000 ppm is 0.76 torr. The saturated vapor pressure, p_s, is taken from Table I.
[b] Experimental values taken from ref. 6.
[c] Calculated from equation 3 using molar volumes.
[d] Calculated from parachors using Sugden's equation.

SL 080920

less than 20%.

The predicted and actual breakthrough times are compared in Table VI and VII. In general, the predicted times are somewhat more optimistic than those determined experimentally. This again can be explained by water's tendency to occupy the available adsorption sites.

Tables VI and VII show conclusively that approximate breakthrough times can indeed be calculated, but only if the activated carbon is well characterized. Approximately twenty-five variables must be known, however, before such calculations can be initiated.

There have been attempts to simplify these calculations by relating the breakthrough time or weight adsorbed directly to a single property of the solvent such as boiling point, molecular weight, vapor pressure, or diffusion coefficient. These oversimplifications generally fail, however, since so many interrelated variables play a role in adsorption.

Effect of Concentration

In a preliminary investigation we varied the concentration, from 125 to 2000 ppm for

TABLE VI
Comparison of Predicted and Actual 10% Breakthrough Times, Type 1 Cartridges*

Material	Time Measured (min)	Calculated from Mecklenburg Equation: Using Experimental Weight Adsorbed (min)	Calculated from Mecklenburg Equation: Using Calculated Weight Adsorbed from Adsorption Isotherm (min)
Benzene	73.3	74.2	92.6
Toluene	94.3	89.4	95.5
m-Xylene	95.7	82.0	92.6
Methanol	0.2	10.9	29.1
Ethanol	28.0	67.6	101
n-Propanol	70.4	115	128
n-Butanol	115	120	116
n-Pentanol	102	101	99.2
Methyl chloride	0.05	3.0	5.9
Ethyl chloride	5.6	13.2	35.6
1-Chloropropane	24.5	41.0	64.3
1-Chlorobutane	32.3	70.8	77.1
Chlorobenzene	107	83.8	99.2
Dichloromethane	10.6	21.6	46.2
1,2-Dichloroethane	54.0	81.2	98.8
1,4-Dichlorobutane	108	96.4	91.9
o-Dichlorobenzene	109	99.6	91.0
Chloroform	13.2	61.0	76.1
1,1,2-Trichloroethane	71.8	98.7	105
Carbon tetrachloride	73.0	73.8	77.3
Perchloroethylene	107	104	99.3
Methyl acetate	32.8	50.7	80.5
Ethyl acetate	66.8	69.1	87.3
n-Propyl acetate	78.8	83.9	84.9
n-Butyl acetate	77.1	91.8	77.0
n-Pentyl acetate	72.6	74.5	69.8

*Test conditions: 53.3 liters/min, 50% relative humidity, and 20°C. Cartridge characteristics are summarized in Tables II and III.

TABLE VII
Comparison of Predicted and Actual 10% Breakthrough Times, Type 2 Cartridges*

Material	Time Measured (min)	Calculated from Mecklenburg Equation: Using Experimental Weight Adsorbed (min)	Calculated from Mecklenburg Equation: Using Calculated Weight Adsorbed from Adsorption Isotherm (min)
Acetone	57.1	58.3	102
2-Butanone	81.9	101	123
2-Pentanone	109	137	121
2-Heptanone	101	116	102
n-Pentane	60.7	77.6	76.6
n-Hexane	52.3	93.7	89.5
n-Heptane	78.2	103	97.1
n-Octane	76.2	89.4	79.2
n-Decane	70.4	90.3	72.2
Methylamine	32.4	33.6	50.0
Ethylamine	40.5	99.3	92.1
n-Butylamine	110	145	125
Di-*n*-butylamine	75.5	86.9	84.4

*Test conditions: 53.3 liters/min, 50% relative humidity, and 20°C. Cartridge characteristics are summarized in Tables II and III.

benzene and from 50 to 2000 ppm for acetone, and measured the effect on service life. The characteristic S-shaped breakthrough curves for these solvents appear in Figures 14 and 15. Although the time to reach a given breakthrough increases as the concentration diminishes, the breakthrough time-concentration relationship is not inversely proportional as one might intuitively suspect. However, a logarithmic plot of the breakthrough time (for example, at 10%) as a function of the concentration yields the linear relationship shown in Figure 16. The resultant empirical equations for the straight lines are:

$$t_{10\ \text{percent}} = 1.4 \times 10^4 \times C_1^{-0.96} \quad \text{for benzene}$$

$$t_{10\ \text{percent}} = 1.1 \times 10^3 \times C_1^{-0.46} \quad \text{for acetone}$$

where $t_{10\ \text{percent}}$ is the time in minutes to achieve a 10% breakthrough, and C_1 is the upstream assault concentration in parts per million. These results conform to the basic Freundlich equation and have been demonstrated previously by Fraust and Hermann.[9]

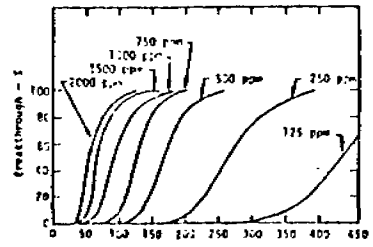


Figure 14. Breakthrough curves for type 1 cartridges, at various concentrations of benzene. Each cartridge pair contained 56.6 ± 1.1 gm of activated carbon and was tested at a flow rate of 53.3 liters/min and 50% relative humidity.

Summary

We have examined the service lives of organic vapor respirator cartridges exposed to aromatics, alcohols, acetates, alkanes, ketones, amines, and chlorinated materials. We assaulted the cartridges under standardized conditions and monitored the downstream concentration to cartridge saturation. The standard test conditions included a sol-

SL 080921

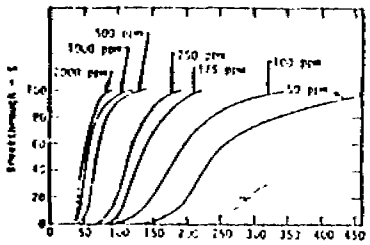


Figure 15. Breakthrough curves for type 2 cartridges at various concentrations of acetone. Each cartridge pair contained 0.5 ± 2.9 gm of activated carbon and was tested at a flow rate of 53.3 liters/min and 50% relative humidity.

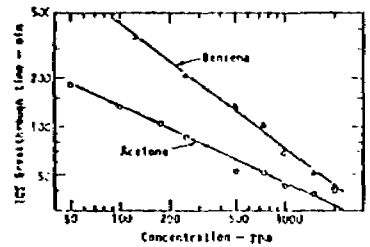


Figure 16. The 10% breakthrough time as a function of concentration for benzene and acetone

vent concentration of 1000 ppm, 50% relative humidity, and a flow of 53.3 liters/min.

Measured breakthrough times agreed reasonably with calculated values obtained from the adsorption isotherm and Mecklenburg equation. In general, the activated carbon has a greater affinity for the less volatile materials.

The relative humidity greatly influences the amount of solvent vapor adsorbed, significantly decreasing the activated carbon's affinity for volatile or water-soluble solvents.

A brief investigation showed that the effect of concentration on breakthrough time conforms to the basic Freundlich equation.

References

1. Ruch, W. E., G. O. Nelson, C. L. Lindeken, R. F. Johnsen, and D. J. Hodgkins, Respirator Cartridge Efficiency Studies: I. Experimental Design, *Amer. Ind. Hyg. Ass. J. 33*: 105 (1972).
2. Nelson, G. O., and D. H. Hodgkins, Respirator Cartridge Efficiency Studies: II. Preparation of Test Atmospheres, *Amer. Ind. Hyg. Ass. J. 33*:110 (1972).
3. Nelson, G. O., R. E. Johnsen, C. L. Lindeken, and R. D. Taylor, Respirator Cartridge Efficiency Studies: III. A Mechanical Breathing Machine to Simulate Human Respiration, *Amer. Ind. Hyg. Ass. J. 33*:745 (1972).
4. Nelson, G. O., and C. A. Harder, Respirator Cartridge Efficiency Studies: IV. Effects of Steady State and Pulsating Flow, *Amer. Ind. Hyg. Ass. J. 33*:797 (1972).
5. Smisek, M., and S. Cerny, *Active Carbon*, pp. 113-115, Elsevier, New York (1970).
6. Friedman, R. W., D. E. Ferber, and A. M. Harrison, Service Lives of Respirator Cartridges Versus Several Classes of Organic Vapors, *Amer. Ind. Hyg. Ass. J. 34*:55 (1973).
7. Perry, J. H. (ed.): *Chemical Engineers' Handbook*, 3rd ed. pp. 536-539, McGraw-Hill, New York (1950).
8. Walker, P. L. (ed.): *Chemistry and Physics of Carbon*, pp. 113-116, Dekker, New York (1966).
9. Fraust, C. L., and E. R. Hermann: The Adsorption of Aliphatic Acetate Vapors onto Activated Carbon, *Amer. Ind. Hyg. Ass. J. 30*: 494 (1969).

Short Course

The annual *Short Course in Fundamentals of Industrial Hygiene* will be presented at the Kettering Laboratory, University of Cincinnati, from October 14-27, 1974. The course, half lecture-half laboratory, will be conducted by the graduate faculty of the Department of Environmental Health. The class will be limited to 20 participants, and the course fee is $600. For information contact Howard Ayer, Kettering Laboratory, 3223 Eden Avenue, Cincinnati, Ohio 45219. (513) 872-5708.

On-Filter Analysis of Quartz in Respirable Coal Dust by Infrared Absorption and X-Ray Diffraction

ROBERT W. FRIEDMAN, SAM Z. TOMA, and HELEN W. LANG

Pittsburgh Mining and Safety Research Center, Bureau of Mines, U.S. Department of Interior, Pittsburgh, Pennsylvania

An infrared spectrometric and an independent X-ray diffraction method were developed for the analysis of α-quartz in airborne respirable coal dust. Sensitivity is such that the procedures can be used for analysis of the material from a single membrane filter such as is used for personal samplers by the Mining Enforcement and Safety Administration (MESA) in its enforcement program. Sensitivity down to less than 10 μg of quartz is obtainable. The methods are reasonably precise with good agreement between them. Their accuracy is limited by the unavailability of a true α-quartz standard. In both procedures dust is transferred ultrasonically from the collection filter to a small area of a new filter which is relatively infrared-transparent and has a weak X-ray background. This technique provides a substantial increase in area concentration and attendant sensitivity. Both methods, in principle, are capable of use with a wide variety of solid materials.

Introduction

THE ANALYSIS OR RESPIRABLE DUST is of importance to industrial hygienists because of the tendency of this form of dust to produce various types of pulmonary disease such as silicosis or coal workers' pneumoconiosis (commonly known as black lung disease). Quartz and other free silica polymorphs are of particular interest because of their toxicity.[1]

At MESA, coal mine dust samples are spot-checked for quartz concentration using a Bureau-developed infrared halide pellet procedure which requires the combining of several samples to provide adequate sensitivity. This method is time-consuming and high individual exposures to quartz can be overlooked due to composite sampling. A procedure with sufficient sensitivity to provide for the analysis of 100 μg or less of quartz collected on a single membrane filter was sought. A rapid procedure is required, since it is anticipated that over 100 samples per day will be analyzed.

Other methods available did not appear adequate. Wet chemical procedures such as the well-known Talvitie Method employing phosphoric acid, differential thermal analysis, optical microscopy, and petrographic analysis are inaccurate, insensitive, and time consuming.[1,2]

As is common with many solids, it is difficult to determine quartz accurately by molecular spectroscopy for physical rather than chemical reasons. This and the difficulty of obtaining reproducible standards will be explained subsequently. Infrared and X-ray diffraction appear to be the best techniques available.[3-5] The samples are pelletized in a relatively inert matrix material such as potassium bromide for infrared or starch for X-ray diffraction.

The concept of using the collection filter itself as a matrix is not new. The use of silver membrane filters was investigated by Leroux and Powers.[3] Samples collected on silver membrane filters were analyzed for quartz using X-ray diffraction. This technique was subsequently tried by Bumsted[6] and by Knight *et al.*[7] Knight noted that the

Mention of commercial products does not imply endorsement by the Bureau of Mines.

SL 080922

EXHIBIT D

The theory of solvent vapor adsorption on activated carbon is reviewed. Calculated and experimental cartridge service life values are compared using various breathing rates, relative humidities, concentrations and solvent vapors. Cartridge service life (the 10% breakthrough time) can be estimated from the emperical expression:

$$t_{10\%} = 2.4 \times 10^5 w_e (a + bt)/C^n MQ$$

Carbon weight (w_e), relative solvent volatility (a, b and t) concentration (C), molecular weight (M) and breathing rate (Q) all play a vital role in cartridge performance predictions.

Respirator cartridge efficiency studies: VIII. summary and conclusions*

GARY O. NELSON and A. NICHOLAS CORREIA
Lawrence Livermore Laboratory, University of California, Livermore, California 94550

Introduction

Many users feel that if cartridges are stamped "PERMISSIBLE CARTRIDGE FOR ORGANIC VAPORS," their effectiveness is guaranteed against all organic vapors. The prevailing rule of thumb indicates that a cartridge can be used until the contaminant vapor is detected inside the mask. However, this may prove a burden for those persons with a moderately developed sense of smell or for those contaminants which have a high odor threshold, but a relatively low threshold limit value. Even individuals with the most acutely developed olfactory senses would experience great difficulty detecting 10 ppm carbon tetrachloride, 1 ppm vinyl chloride or 0.1 ppm acrolein. Clearly, there is a compelling need to know the limitations and duration of cartridge effectiveness if maximum respiratory protection is to be achieved.

The amount of experimental cartridge service life data is sparse. There have been, however, a great number of reports generated in the literature concerning activated carbon which is the prime adsorbing ingredient in organic vapor respirator cartridges. However, the problem exists in selectively extracting the relevant data and applying it in a simplified fashion to the field industrial hygiene problems related to respiratory protection.

The purpose of this report is to summarize our 5-year respirator cartridge study.[1-7] We will (1) describe activated carbon, the primary cartridge ingredient, and the vapor entrapment process; (2) show how fundamental adsorption theory is used to predict service life and what role each variable plays; (3) test the theoretical models with experimental data and show where discrepancies exist; and (4) reduce the theoretical complexities and propose a relatively simplified empirical expression which will provide valid estimations of respirator cartridge performance.

These results and equations can not only be used to evaluate cartridge service life characteristics, but can also be applied to any process using high-grade activated carbon as the adsorbing media. This includes charcoal sam-

*This work was performed under the auspices of the U.S. Energy Research & Development Administration, under contract No. W-7405 Eng 48.

NOTICE—this report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Energy Research & Development Administration, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

*For more information about authors, see page 550 . . .

SL 080923

TABLE 1
Manufacturing Specifications of Organic Vapor Half-Mask Respirator Cartridges.*

MANUFACTURER	MODEL NO.	TOTAL CARBON WEIGHT, w_c† (g)	CARBON DENSITY, ρ_c (g/cm³)	CARBON BASE
American Optical Co.	R 51	74	0.43	Petroleum
Bausch and Lomb	Organic Vapor	80	0.43	Petroleum
Glendale Optical Co.	GR 4021, GR 3021	80	0.43	Petroleum
Mine Safety Appliance Co.	44135	52	0.38	Coconut
	459315	68	0.40	Coconut
	76883**	51	0.43	Various
Safeline Products	5061	74	0.43	Petroleum
Scott Aviation	800-OV	80	0.40	Petroleum
	502 OV**	85	0.46	Petroleum
Welch Manufacturing Co.	7500-1	69	0.14	Petroleum
Wilson	R 21	97	0.44	Petroleum

*Each mask uses two cartridges except where otherwise indicated.
†Weight of both cartridges.
**Single-cartridge respirator

pling tubes, full face mask canisters, as well as large bed industrial processes.

Experimental

Respirator cartridges

The typical organic vapor half-mask respirator cartridge is a plastic or metal case which contains from 25-40 g of adsorbing media. Currently the only material used is activated carbon. Sometimes the carbon is impregnated with metallic salts to enhance its acid gas adsorption characteristics. However, the only material that takes an active part in the sorption process is the highly porous carbon.

Activated carbon can be manufactured from literally any material which contains carbon in its elemental or chemically bound form. Seaweed, coffee grounds, coal, and peach pits have been used, but currently all of the carbon used in the respiratory protective field originates from a coconut shell or petroleum base. The coconut variety is the more traditional material, but the petroleum base material is enjoying an upswing in popularity and is currently used largely for economic reasons. These two types are shown in the electron micrographs in Figure 1. The size generally varies from 8 to 20 mesh with an average particle diameter of approximately 0.5 to 1 mm. The coconut base is more angular while the petroleum base is more nearly spherical. Both types exhibit the highly developed microporous surface required for maximum adsorption.

The MSA (Model 44135—coconut base)* and the AO (Model R-51—petroleum base)

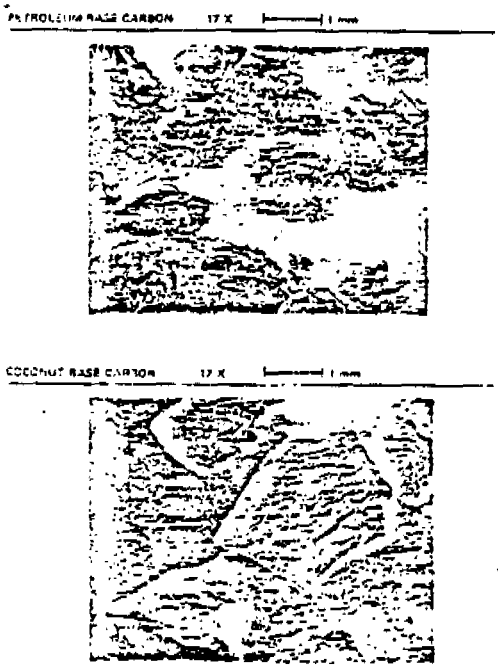


Figure 1 - Electron micrographs of coconut and petroleum base activated carbon granules.

*Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research & Development Administration to the exclusion of others that may be suitable

SL 080924

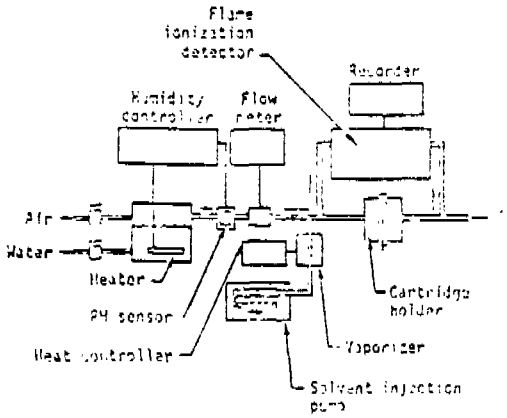


Figure 2. Schematic of the apparatus used to produce known concentrations of solvent vapor in humidified air.

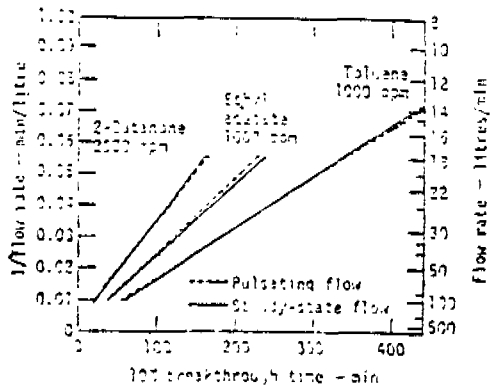


Figure 3. Comparison of steady state and pulsating flow using three solvents. The service life is inversely proportional to flow and independent of flow uniformity.

were chosen for testing because they were representative of the commercially available cartridge types (see Table I). Their complete specifications are outlined in Table I of Reference 6

Breathing simulator

It was originally thought that pulsating rather than a steady-state flow would yield a more accurate estimate of cartridge performance. Thus we constructed the mechanical breathing simulator shown in Reference 4. Such a device produces work rates of 0, 208, 415, 622, 830, and 1107 kg-m/min with a corresponding minute volume (average flow) of 14.0, 20.6, 29.8, 36.7, 53.3, and 71.4 liters/min respectively. The breathing simulator proved useful during the early stages of our testing program, but it later was discontinued and only steady flow techniques were utilized.

Preparation of test atmospheres

Figure 2 shows the apparatus for producing test concentrations. Laboratory compressed air passes over a water reservoir. A heater in the reservoir, activated by a humidity controller, automatically maintains any preset relative humidity. The humidified airflow is set and measured with a mass flowmeter. The solvent is injected with a pulseless microflow pump through a heated needle where it is vaporized. The gas mixture then passes through the cartridges to be tested. Two flame ionization detectors continuously monitor both the upstream and downstream concentrations. This system is described in great detail in Reference 2, and modifications are given in References 4-6.

Cartridge preconditioning and testing

Cartridges were first vacuum dried at for at least 24 hours at 110°C to determine the dry weight of the activated carbon. They were then preconditioned in a humidity cabinet for periods up to one week to a constant weight and the amount of water uptake was noted.

Early in the testing program, cartridges were tested individually to determine if there were any large differences in performance at a given set of conditions. However, little difference was noted, and we began testing cartridge pairs. All the data shown in this report are based on results using a two-cartridge system.

Base testing conditions were 1000 ppm solvent vapor, 53.3 liters/min, 22°C and a 50% preconditioning and test relative humidity. However, we departed from these values, depending on the specific variable of interest.

The time to reach 10% breakthrough signalled the end of effective cartridge service life. Testing, however, was continued until they were completely spent and total saturation was achieved. The weight of adsorbed solvent vapor and moisture was determined by the technique outlined in Reference 4.

Results

Effect of flowrate

Cartridges were tested from 14 to 71.4 liters/

SL 080925

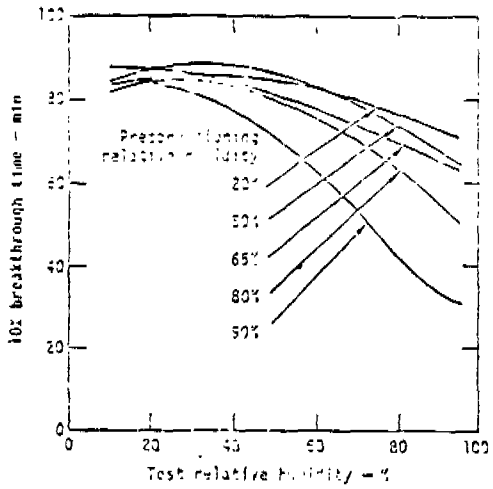


Figure 6–The service life as a function of both storage and use humidity for MSA cartridges at 1000 ppm 1-chlorobutane. Above 65% humidity, the service life experiences a significant reduction.

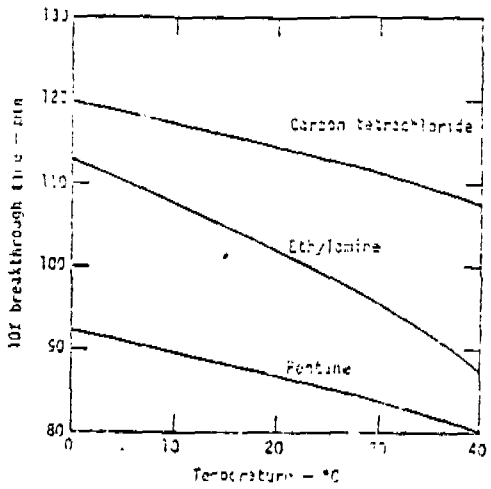


Figure 7–Calculated cartridge performance as a function of temperature. Breakthrough times are diminished between 1-10%, with each 10°C rise in temperature.

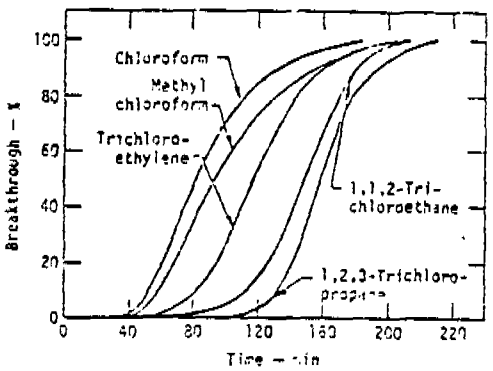


Figure 8–Service life curves for the trichlorinated hydrocarbon family showing the breakthrough percentage as a function of time. The service time cannot be directly related to a single solvent property but is a complex function of the vapor, carbon type and ambient conditions.

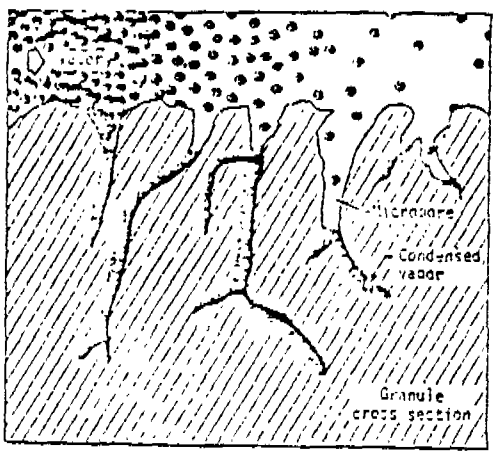


Figure 9–The adsorption process. Molecules diffuse into the carbon granule, are attracted by vander Waals forces, and then are condensed in the micropores.

TABLE III
Breakthrough Time Correction Factors at Various Humidities at 1000 ppm

USE RELATIVE HUMIDITY (%)	BREAKTHROUGH TIME MULTIPLIER AT 1000 PPM* STORAGE RELATIVE HUMIDITY (%)					
	0	20	50	65	80	90
0	0.94	0.95	0.99	0.97	0.95	0.95
20	1.02	1.02	1.03	1.04	1.01	1.00
50	0.98	0.99	1.00	0.97	0.95	0.77
65	0.97	0.93	0.99	0.94	0.84	0.66
80	0.87	0.91	0.88	0.83	0.72	0.50
90	0.84	0.85	0.83	0.78	0.67	0.48

*The data have been normalized to the 50% use and storage humidities.

Effect of rela
The water v
a profound
Figure 5, fo
ative humic
(2) the effec
vapor conce
um or store
humidity at
Figure 6 sh
bined influe
humidity de
above 65%
bution is mi
ty correctio
These data
concentratio
and use hur
reference co

Effect of tem
The only ter
between 20-
been done, i
ing undilute
and calculati
7 shows the
several solve
Such calculat
times are dir
10°C rise in

Effect of solv
We have me
vent vapors
cohols, alka
nated mater
through cur
trichlorinate

In gen
greater affin
However, cu
the cartridge
por property
plex functio
carbon, and
tions. This i
tion on calc
and theoretic

Effect of carti
Cartridge se
amount of c

American Industrial

SL 080926

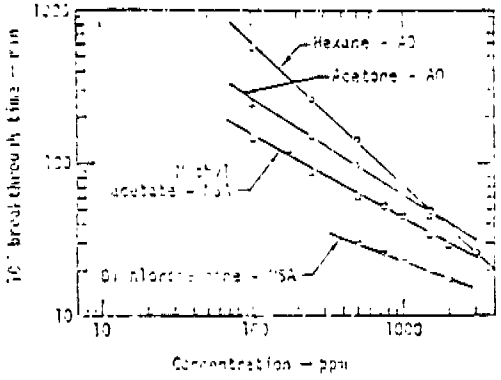


Figure 4—The service life as a function of concentration. Test conditions include a flowrate of 53.3 liters/min at 50% relative humidity. Decreasing the concentration by a factor of 10 generally increases the service life four to five times

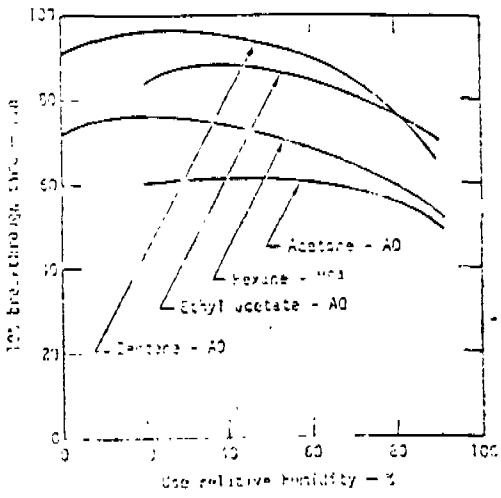


Figure 5—The service life as a function of use humidity. Water vapor content does not appreciably affect cartridge performance below 50% relative humidity. Capacity is more pronounced at 85% relative humidity

min with both a steady-state and pulsating flow using the breathing simulator. Typical results showing the 10% breakthrough time for three solvents as a function of flowrate are shown in Figure 3. No significant service life difference was observed between the two flow types at 1000 ppm. This conforms to adsorption theory which predicts that the amount of solvent adsorbed on a given activated carbon is independent of flowrate and depends only on concentration, temperature, humidity and solvent type. The breakthrough time, therefore, is governed only by the average flow rather than the uniformity of flow. Based on these results, testing with the breathing simulator was discontinued, and all subsequent testing was done with the steady-state mode.

Figure 3 also shows that the breakthrough time is inversely proportional to flowrate. Thus, halving the flowrate will essentially double the service life if the other conditions remain the same. We have observed no violations of this law during normal breathing conditions (see Table II). However, for extremely thin carbon beds or for flows greater than 200 liters/min (far outside the realm of human respiration) some deviation may occur.

Effect of concentration

Examples of the effects of concentration on cartridge performance are shown in Figure 4. The time to any given breakthrough percent (t_b) conformed to the expression

$$t_b = a_1 C^{b_1} \qquad (1)$$

where C is the challenge concentration and a_1 and b_1 are constants for a given set of experimental conditions. In other words, the service life is inversely proportional to the log of the concentration. The average value for b at 10% breakthrough was −0.67 for a concentration range of 50-3000 ppm. Thus if the service time is known at one vapor concentration, the service life at other concentrations can be *approximated* by

$$t_b = t_b' (C'/C)^{2/3} \qquad (2)$$

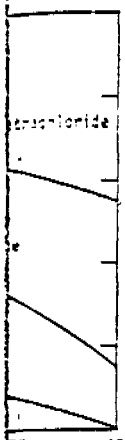
where t_b' is the known time at a concentration C' and C is new concentration at which the time t_b is desired.

In general if the concentration is diminished by a factor of 10, the service time will increase by a factor of 4 or 5. This is consistent with adsorption theory which predicts that less solvent is adsorbed at lower concentrations.

TABLE II
Breathing Rate as a Function of Work Rate

WORK RATE DESCRIPTION	WORK RATE (KG M/MIN)	AVERAGE BREATHING BREATHING RATE (LITERS/MIN)
Sitting	0	14
Light	203	21
Moderate	415	30
Moderately heavy	622	37
Heavy	830	55
Extremely heavy	1107	75

SL 080927



...ance as a
...n times are
...10°C rise in

...ecules diffuse
...d by vander
...in the micro-

Effect of relative humidity

The water vapor content of the ambient air has a profound effect on cartridge performance. Figure 5, for example, shows: (1) that high relative humidities depress the service life, and (2) the effect is more pronounced as the solvent vapor concentration diminishes. The equilibrium or storage conditions as well as the use humidity also govern cartridge effectiveness. Figure 6 shows a typical example of the combined influence of both effects. Increasing the humidity depresses the service life, especially above 65% humidity. Below 50% the contribution is minimal. Breakthrough time humidity correction factors are given in Table III. These data were obtained from solvent vapor concentrations of 1000 ppm. The 50% storage and use humidity is arbitrarily defined as the reference condition.

Effect of temperature

The only temperature used for our testing was between 20-25°C. Much previous work has been done, however, at other temperatures using undiluted solvent vapors, and the results and calculations are well documented.[3] Figure 7 shows the calculated 10% breakthrough for several solvents as a function of temperature. Such calculations indicate that the breakthrough times are diminished between 1-10% with each 10°C rise in temperature.

Effect of solvent vapor

We have measured the service life for 131 solvent vapors and gases including aromatics, alcohols, alkanes, ketones, amines and chlorinated materials. An example of the breakthrough curves is shown in Figure 8 for the trichlorinated hydrocarbons.

In general, the activated carbon has a greater affinity for the less volatile materials. However, currently no method exists to relate the cartridge service life to a single solvent vapor property. The breakthrough time is a complex function of the solvent vapor, activated carbon, and the prevailing experimental conditions. This is explained more fully in the section on calculations where both experimental and theoretical values are given.

Effect of cartridge size and configuration

Cartridge service life depends directly on the amount of carbon available. If one doubles the size of the adsorption bed, the service time will also be doubled.

Cartridge configuration or shape plays no role in performance except in exceptionally thin beds. One problem which may inhibit performance is channeling caused by an incompletely filled cartridge. This would be rare, however, for we have never observed a single example of channeling in the 2000 cartridges we have tested. Commercial filling and cartridge case sealing techniques minimize loose carbon packing by allowing the case cover to exert a slight spring tension on the carbon fill.

Calculations

Introductory theory

Adsorption theory has changed significantly over the past 50 years. The Langmuir and BET equations have yielded to the Dubinin and Polanyi adsorption isotherm equations based on potential theory.[4] These is still not sufficiently developed to cope with complex mixtures of solvent vapors, or to correct for the presence of water vapor. The following discussion will, however, help clarify fundamental theory and give the reader a better understanding of the way organic vapor respirator cartridges function.

The adsorption process for a single carbon granule is shown in a cross section in Figure 9. Here the air-vapor mixture is shown flowing across the granule. As the vapor diffuses into the pores, it migrates to the carbon surface and condenses in the pores. The pores continue to fill until some maximum value is achieved, depending on prevailing conditions. A high degree of pore filling is noted at high concentrations of relatively nonvolatile solvent vapors.

An assemblage of adsorbing carbon granules produces the situation shown in Figure 10. Here the concentration at any point in the bed is shown as a function of bed depth, and the shading on the cartridge offers a visual indication of the relative amount of solvent adsorbed. The assault or challenge concentration is indicated as C_0, and the curve generated is generally termed the adsorption wave. Figure 10(a) shows the cartridge adsorbing all the vapor in the first layers of the cartridge. Figure 10(b) shows the first layers completely saturated, and the intermediate layers partially saturated. Initial breakthrough is just

SL 080928

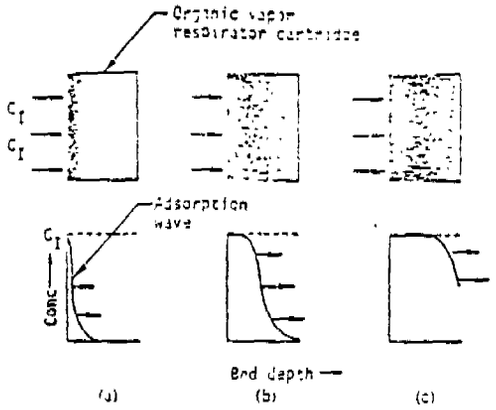


Figure 10—Cartridge loading patterns and migration of the adsorption wave through the carbon as a function of time

beginning on the downstream cartridge surface. Figure 10(c) shows the cartridge almost completely saturated at 50% breakthrough. The breakthrough curve, which shows the effluent cartridge concentration as a function of time, is actually a mirror image of the shape of the adsorption wave.

The adsorption isotherm

To ascertain the service life, one must first calculate the amount of solvent vapor present at cartridge saturation. This can be done using the adsorption isotherm which states that maximum weight of solvent adsorbed can be calculated from

$$w_s = \rho W_o \exp\left\{\frac{-BT^2}{\beta^2}[\log(p_s/p)]^2\right\} \qquad (3)$$

where

- w_s = equilibrium static adsorptive capacity per unit weight carbon (g/g),
- ρ = density of solvent (g/cm³),
- W_o = total volume of adsorption space (cm³/g),
- B = microporosity constant for the carbon,
- T = temperature (°K),
- β = affinity coefficient of solvent vapor for the activated carbon
- p_s = saturated vapor pressure (kPa) for the solvent at temperature T, and
- p = equilibrium partial pressure of the solvent vapor (kPa).

The terms W_o and B are interrelated, and can be determined experimentally for each carbon type by the technique outlined in Reference 6. Typical values are 0.6 and 1.2×10^{-5} respectively. The affinity coefficient β characterizes the absorption of a given vapor with respect to benzene (for which $\beta = 1$ by definition). The β term can either be determined by experiment or approximated by

$$\beta \approx \frac{\rho_{oH}\, M}{M_{oH}\, \rho} = \frac{0.0113M}{\rho} \qquad (4)$$

where

- ρ, ρ_{oH} = solvent density for the unknown and standard solvent (g/cm³),
- M, M_{oH} = molecular weights for the unknown and standard solvent) g/mole)

The term w_s is the weight adsorbed at total saturation—that is, at 100% breakthrough. Initial breakthrough, however, occurs long before the equilibrium adsorptive capacity is established. Nevertheless, such breakthrough times can be estimated from the Mecklenburg or the modified Wheeler equation.

The Mecklenburg equation

The Mecklenburg equation states that

$$t_b = \frac{w_s \rho_c A n}{QC_o}\left[z + \frac{1}{a_v \rho_c}\left(\frac{dG}{\eta}\right)^{0.41}\left(\frac{\eta}{\rho_a D}\right)^{0.67} \ln(C_b/C_t)\right] \qquad (5)$$

where

$$C_o = \frac{MC_t}{24.2 \times 10^3},$$

$$G = \frac{1000\, \rho_a\, QV_{\rho_a}}{60An},$$

$$z = V/A.$$

and

- t_b = breakthrough time (min)
- ρ_c = carbon density (g/cm³),
- A = cross-sectional area of the adsorbent bed (cm²),
- V = carbon volume (cm³),
- n = number of cartridges tested,
- C_o = assault concentration (g/liter),
- z = bed depth (cm),
- a_v = specific surface area (cm²/g),
- d = diameter of granule (cm),
- G = mass velocity through cartridge (g/cm²-sec),
- η = viscosity of the air-gas stream (g/cm-sec),
- ρ_a = density of air-vapor stream (g/cm³),
- D = diffusion coefficient (cm²/sec),
- C_b = breakthrough concentration (ppm),
- C_t = assault concentration (ppm),
- V_v = void volume (cm³/g),
- Q = flowrate (liters/min).

SOLVENT

Benzene*

Benzene†

Toluene*

Methanol*
Isopropanol*

Butanol*
Pentanol*
Vinyl chloride†

Ethyl chloride†
1-Chlorobutane

Chlorobenzene
Dichlorometha

o-Dichlo
Chlorofo
Methyl chlorof

Trichloroethyle
Carbon tetrach

Perchloroeth
Methyl acetat

Ethyl acetate†

Propyl acetate†
Butyl acetate*
Acetone*

Acetone†

2-Butanone**
Diisobutyl Ketc
Pentane**
Hexane†

Hexane*

Cyclohexane**
Heptane**
Methylamine**
Ethylamine**
Diethylamine*

Dipropylamine*

*3M 9A cartrid
†AO cannister
**AO cartridg
††Use humidi

American Indust

SL 080929

TABLE IV

Comparison of Experimental and Calculated 10% Breakthrough at 22°C

SOLVENT	CONCENTRATION (PPM)	FLOW RATE (LITERS/MIN)	TEST RELATIVE HUMIDITY (%)	10% BREAKTHROUGH TIME: CALCULATED MECKLENBURG EQ. (MIN)	CALCULATED WHEELER EQ. (MIN)	CALCULATED EQUATION (16) (MIN)	EXPERIMENTAL (MIN)
Benzene*	125	53.3	50	440	413	377	355
	500	53.3	50	169	161	150	134
	2000	53.3	50	59.3	56.4	59.4	41.9
Benzene†	1000	53.3	20	114	110	126††	101
	1000	53.3	50	114	110	127	101
	1000	53.3	80	114	110	112††	87.4
Toluene*	1000	20.5	50	328	322	255	239
	1000	36.7	50	180	174	143	151
	1000	53.3	50	121	116	98.7	114
Methanol*	1000	53.3	50	8.5	7.9	−0.5	3.2
Isopropanol*	500	53.3	50	170	160	77.5	126
	2000	53.3	50	73.1	63.3	30.7	54.7
Butanol*	1000	53.3	50	150	141	130	141
Pentanol*	1000	53.3	50	137	124	120	120
Vinyl chloride†	50	40	50	90.2	96.2	−69.1	77.0
	250	40	50	55.6	55.3	−22.6	52.5
	1000	40	50	30.4	31.4	−0.4	22.7
Ethyl chloride*	1000	53.3	50	21.5	18.5	26.5	10.7
1 Chlorobutane*	1000	53.3	20	89.0	87.2	75.5††	89.3
	1000	53.3	50	89.0	87.2	73.3	87.3
	1000	53.3	90	89.0	87.2	61.0††	69.0
Chlorobenzene*	1000	53.3	50	132	124	97.9	131
Dichloromethane*	500	53.3	50	30.3	28.5	44.5	30.0
	2000	53.3	50	21.1	19.7	17.7	17.3
o-Dichlorobenzene*	1000	53.3	50	132	130	124	132
Chloroform*	1000	53.3	50	69.9	66.6	51.9	52.4
Methyl chloroform*	250	53.3	50	251	242	149	207
	2000	53.3	50	51.3	49.5	37.2	56.1
Trichloroethylene*	1000	53.3	50	108	103	72.6	83.0
Carbon tetrachloride*	1000	53.3	20	82.4	79.1	89.4††	84.9
	1000	53.3	50	82.4	79.1	85.8	68.8
	1000	53.3	90	82.4	79.1	71.3††	66.0
Perchloroethylene*	1000	53.3	50	128	123	112	120
Methyl acetate*	100	53.3	50	373	353	248	145
	1000	53.3	50	73.9	81.8	53.1	45.9
Ethyl acetate†	1000	53.3	20	115	111	83.1††	88.4
	1000	53.3	65	115	111	79.0††	90.4
	1000	53.3	90	115	111	67.2††	68.4
Propyl acetate*	1000	53.3	50	110	106	72.4	90.0
Butyl acetate*	1000	53.3	50	106	104	87.1	96.9
Acetone†	100	53.3	50	504	484	499	244
	500	53.3	50	160	154	170	96.7
	1000	53.3	50	91.4	90.8	107	66.3
Acetone†	1000	53.3	20	94.4	90.8	110††	61.1
	1000	53.3	80	91.4	90.8	94.3††	54.5
	1000	53.3	90	91.4	90.8	89.0††	53.1
2-Butanone**	1000	53.3	50	136	132	103	94.4
Diisobutyl Ketone**	1000	53.3	50	97.4	97.2	101	83.3
Pentane**	1000	53.3	50	86.2	83.8	67.5	71.3
Hexane†	100	53.3	50	646	631	420	565
	500	53.3	50	156	152	144	143
	2000	53.3	50	44.1	43.0	57.0	37.9
Hexane*	1000	53.3	0	77.6	75.4	66.7††	76.7
	1000	53.3	65	77.6	75.4	66.7††	68.1
	1000	53.3	90	77.6	75.4	56.6††	64.0
Cyclohexane**	1000	53.3	50	121	122	90.4	82.3
Heptane**	1000	53.3	50	105	104	84.9	80.5
Methylamine**	1000	53.3	50	49.1	46.7	13.4	17.9
Ethylamine**	1000	53.3	50	99.9	96.1	57.1	49.7
Diethylamine*	250	53.3	50	117	110	170	92.5
	1000	53.3	50	52.7	49.8	71.0	35.6
	2000	53.3	50	33.7	31.9	44.7	20.5
Dipropylamine**	1000	53.3	50	141	110	110	105

*MSA cartridges, coconut base, 52.2 g/pair.
†AO cartridges, petroleum base, 70.5 g/pair.
**AO cartridges, coconut base, 62.2 g/pair.
††Use humidity correction from Table III

SL 080930

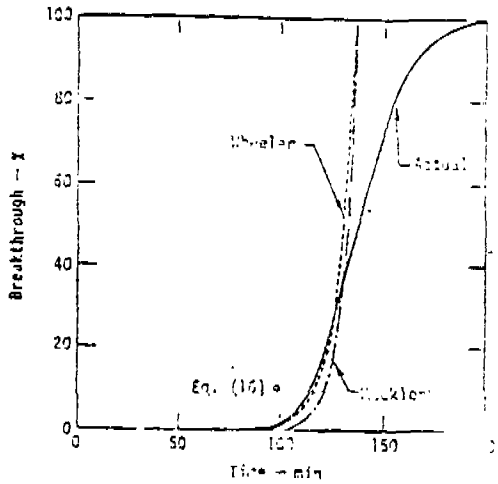


Figure 11—Comparison of calculated and experimental breakthrough curves for toluene. Tests were made at 100 ppm, 50% relative humidity and 32.3 liters/min. The 10% breakthrough point calculated from Eq. (16) is also shown. The calculated curves closely approximate the shape and magnitude of the experimental data from 0-40% breakthrough.

The terms A, ρ_b, V, n, z, a_c, d and V_s are all constants for a given cartridge type, M, D, η and ρ_a are constants pertaining to the solvent vapor and air mixtures, and Q, C_o, C_m, C_t and G are variables, depending on the prevailing ambient conditions. Further explanation and examples of the constants and variables are worked out in detail in References 5 and 6. Use of the Mecklenburg equation, although surprisingly accurate (see Table IV for comparisons with experimental values), is hindered because of its complexity and the general unavailability of many of the experimental constants.

The Wheeler equation

The modified Wheeler equation represents a major simplification in the breakthrough time calculation.[9,10] It can be expressed as

$$t_b = \frac{W_e}{C_o Q}\left[W_e - \frac{1000\rho_c Q}{k_v} (\ln C_t/C_o) \right] \quad (6)$$

where

$$C_m = M C_t/24.2 \times 10^6$$

and

$$K_v = 14.4 v_t^{1/2} d^{-1/2} = 14.4 (1000 Q/nA)^{1/2} d^{-1/2}.$$

Here k_v is the adsorption rate constant (min^{-1}), v_t represents the superficial velocity across the particle (cm/min), and W_e is the weight of the carbon (g).

Figure 11 shows a comparison of curves calculated from the Wheeler and Mecklenburg equations with actual data for toluene. Both calculated curves have approximately the same shape as the experimental curve between 0 and 40% breakthrough, but are displaced by varying degrees from the actual data. Comparison of actual and theoretical service life values for 10% breakthrough at 22°C are shown in Table IV.

Development of a simple empirical tion to estimate cartridge service life

The equations shown in the preceding section are based on the best available adsorption theory, and are indeed a great aid in predicting cartridge service drawbacks: (1) the difference between the actual and theoretical service life is significant, especially when using relatively volatile materials; and (2) such expressions are complicated and require knowledge of the ambient conditions as well as the physical properties of the solvent vapor and activated carbon. It would be of considerable benefit, therefore, if a relatively simple expression could be developed which would be of use to the field industrial hygienist as well as other safety personnel in the industrial community.

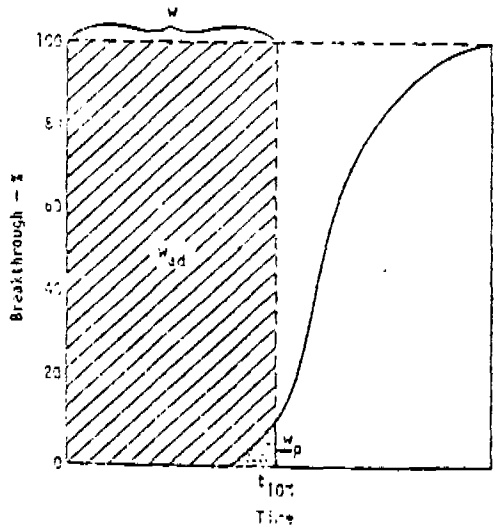


Figure 12—Percent breakthrough (rate of solvent vapor adsorbed) as a function of time. Typically only ~2% of the solvent vapor has penetrated the cartridge at 10 breakthrough.

SL 080931

Consider a closed environment containing a vapor which is distributed homogeneously throughout its volume. At room temperature (22°C) and pressure (100 kPa), the concentration (ppm) can be represented by

$$C = \frac{24.2 \times 10^3 w_v}{MV} \quad (7)$$

where w_v is the weight of vapor (g), V is the enclosure volume (liters) and M is the molecular weight. If this concentration is drawn through a cartridge of weight w_c (g) at a breathing rate of Q (liters/min), the resultant amount of vapor which contacts the adsorbent in a time t (min) is

$$w = \frac{CMQt}{24.2 \times 10^3 w_c} \quad (8)$$

where w is the weight of vapor per weight adsorbent g/g). The term w can also be expressed as

$$w = w_{ad} + w_p \quad (9)$$

where w_{ad} is the amount of vapor actually adsorbed and w_p is the amount which passes through the cartridge unadsorbed.

Let us arbitrarily define the practical service life of the cartridge as $t_{10\%}$, the time required to achieve 10% breakthrough. The amount of solvent coming in contact with adsorbent w is represented by the cross-hatched area in Figure 12. The amount actually adsorbed, w_{ad}, is shown as the white cross-hatched area while the vapor which penetrates the cartridge, w_p, is the grey cross-hatched area. Assuming w_p is small enough to neglect, Eqs. (8) and (9) can be combined and rearranged to

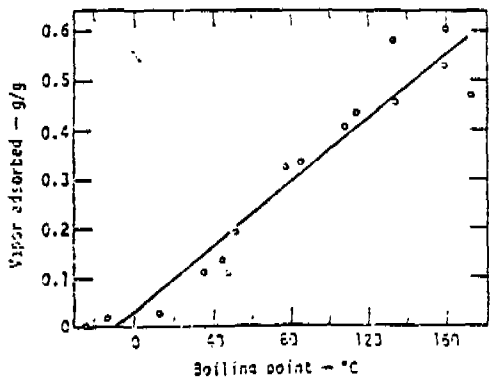


Figure 13–Weight solvent vapor adsorbed at 1000 ppm as a function of normal boiling point for monochlorinated hydrocarbons.

TABLE V
Solvent Class Coefficients

SOLVENT TYPE	BOILING POINT RANGE (°C)	COEFFICIENTS A	B
Acetates*	50 to 190	−0.030	0.0038
Alcohols*	60 to 160	−0.16	0.0071
Alkanes	20 to 200	0.075	0.0022
Alkyl benzenes	80 to 220	0.12	0.0024
Amines*	−10 to 200	0.037	0.0022
Ketones	50 to 220	0.034	0.0020
Monochlorides	−30 to 220	0.032	0.0033
Dichlorides	40 to 210	−0.022	0.0043
Trichlorides	60 to 190	−0.030	0.0056
Tetrachlorides	70 to 220	0.13	0.0043

*Lower boiling solvents weighted more heavily when determining coefficients

$$t_{10\%} = \frac{24.2 \times 10^6 w_c w^\circ_{ad}}{CMQ} \quad (10)$$

All the parameters of Eq. (10) are known except w_{ad} which is a complex function of the solvent physical properties as well as the concentration. w_{ad} can be calculated for 1000 ppm (termed w°_{ad} or the weight adsorbed at the reference concentration) from the data in Reference 5 using experimental breakthrough times determined for the 10 classes of solvent vapors. w_{ad} must now in some manner be related to some easily determined property so that w°_{ad} for untested vapors can be estimated knowing only a single physical property.

Several properties were considered. Among them were molecular volume, density, vapor pressure, boiling point, critical temperature, magnetic susceptibility, and molecular weight. The normal boiling point was chosen because of its general availability and good correlation as an increasing function of the solvent weight adsorbed.

An example of w°_{ad} as a function of normal boiling point is shown in Figure 13 for monochlorides. The best straight line has been determined using a first-degree fit. This was done for each of the ten classes of compounds, and the coefficients are shown in Table V. Therefore, knowing the solvent vapor class and the boiling point, the weight adsorbed at 10% breakthrough at 1000 ppm can be calculated from

$$w^\circ_{ad} = a + bt \quad (11)$$

where a (intercept) and b (slope) are the coefficients from Table V and t is the boiling point in degrees Celsius.

As previously mentioned, w°_{ad} is dependent on concentration but not affected by flowrate of minor temperature fluctuations. As the concentration decreases, the relative amount

SL 080932

of vapor adsorbed also decreases. If the w°_{ad} is plotted as a function of concentration on logarithmic coordinates, a linear relationship is observed as shown by the examples in Figure 14. This line takes the form

$$w_{ad} = k\,C^{m} \tag{12}$$

where w_{ad} is the weight adsorbed, m is the slope the line, and k is a constant. At the reference concentration, 1000 ppm, w°_{ad} becomes

$$w^{\circ}_{ad} = k\,(1000)^{m} \tag{13}$$

Dividing Eq. (12) by Eq. (13),

$$w_{ad} = w^{\circ}_{ad}\left(\frac{C}{1000}\right)^{m} \tag{14}$$

We have determined m experimentally for the ten materials shown in Table VI. The average value was found to be 0.36 or approximately the cube root of the concentration ratio.

Combining Eqs. (10) and (14) and letting m equal 1/3 yields

$$t_{10\%} = \left[\frac{2.2 \times 10^{6}\, W_e}{CMQ}\right] w^{\circ}_{ad}\left(\frac{C}{1000}\right)^{1/3} \tag{15}$$

Combining Eqs. (11) and (15) and simplifying terms yields

$$t_{10\%} = \frac{2.4 \times 10^{6}\, w_e\,(a + bt)}{C^{2/3}\,MQ} \tag{16}$$

This expression can be used to calculate the 10% breakthrough time by obtaining M and t from handbook values, C by estimation or measurement, w_e by weighing or from Table I, Q from Table II, and a and b from Table VI. This equation is a good approximation in the 0-40°C temperature range, but a humidity factor must be added for unusually humid conditions (see preceding section on relative humidity) or if the carbon has been stored in a damp environment.

Comparison of Eq. (16) with the Mecklenburg and Wheeler equations for 10% breakthrough is shown in Table IV and Figure 11. In general, Eq. (16) shows the best agreement with experimental values, especially at the higher concentration using relatively volatile materials. This expression does have several disadvantages: (1) Only the 10% breakthrough time can be calculated, (2) it cannot adequately deal with solvent mixtures and (3) no provisions are made for materials with more than one functional group. In spite of these deficiencies, Eq. (16) offers a rapid method of service life estimation over a broad range of flows, concentrations, humidities, and solvent vapors.

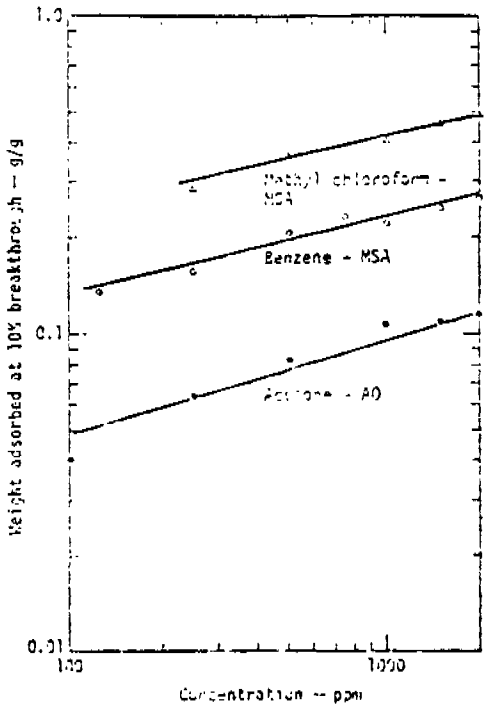


Figure 14–Weight of solvent vapor adsorbed as a function of concentrations.

Summary

We have determined the service life for organic vapor cartridges under a wide variety of flow, concentration, humidity and solvent vapor conditions. Cartridges were challenged with vapor and air mixtures and the downstream concentrations were measured with a flame ionization detector.

Service life was found to be inversely proportional to the flowrate, and no differences were observed between steady state and pulsating flow. The log of the service time at any breakthrough percent was inversely proportional to the log of the concentration over a concentration range of 50 to 3000 ppm.

Cartridge effectiveness was decreased at storage or use humidities above 65% with use humidity exhibiting the dominating effect. The service time was found to be directly proportional to the amount of carbon available, but

SL 080933

TABLE VI
Experimental Values for the Slope (m) of the Line Obtained When the Weight Adsorbed at 10% Breakthrough is Plotted as a Function of Concentration on Logarithmic Coordinates

	CARTRIDGE	CONCENTRATION RANGE (ppm)	SLOPE (m)
Ethylamine	MSA	250-2000	0.32
Acetone	AO	100-2000	0.33
Benzene	MSA	125-2000	0.23
Dichloromethane	MSA	500-2000	0.59
Hexane	AO	100-2000	0.10
Methyl chloroform	MSA	250-2000	0.25
Methyl acetate	MSA	100-2000	0.46
Isopropanol	MSA	500-2000	0.39
Carbon tetrachloride	MSA	750-2000	0.34
Vinyl chloride	AO	50-2000	0.56
		Average =	0.35 ± 0.15

did not depend appreciably on temperature. Volatile materials, especially the first members of each homologous group (i.e., methanol, methyl amine, methyl chloride, etc.) exhibited relatively short breakthrough times.

An empirical expression to estimate the service time was derived which compares favorably with experimental values and those calculated from the Mecklenburg and Wheeler equations.

Acknowledgments

Since this program began 5 years ago, a number of individuals have contributed significantly to the success of the project. We gratefully acknowledge Joe Lipera and Walter Ruch for their assistance in initiating our testing program. We also wish to thank Robert S. Flint, Thomas Tassia, Joe R. Parlagreco, and Patrick F. Barry for their help in programming and data reduction, and to thank Robert D. Taylor and Bernell J. Bequette for their skillful engineering support. We would also like to express our appreciation to Charles T. Prevo for his efforts in developing our empirical expressions.

References

1. Ruch, W. E., G. O. Nelson, C. L. Lindeken, R. E. Johnson and D. J. Hodgkins: Respirator Cartridge Efficiency Studies: I. Experimental Design. *Am. Ind. Hyg. Assoc. J. 33*:105 (1972).
2. Nelson, G. O. and D. J. Hodgkins: Respirator Cartridge Efficiency Studies: II. Preparation of Test Atmospheres. *Am. Ind. Hyg. Assoc. J. 33*:110 (1972).
3. Nelson, G. O., R. E. Johnson, C. L. Lindeken and R. D. Taylor: Respirator Cartridge Efficiency Studies: III. A Mechanical Breathing Machine to Simulate Human Respiration. *Am. Ind. Hyg. Assoc. J. 33*:745 (1972).
4. Nelson, G. O. and C. A. Harder: Respirator Cartridge Efficiency Studies: IV. Effects of Steady State and Pulsating Flow. *Am. Ind. Hyg. Assoc. J. 33*:797 (1972).
5. Nelson, G. O. and C. A. Harder: Respirator Cartridge Efficiency Studies: V. Effects of Solvent Vapor. *Am. Ind. Hyg. Assoc. J. 33*:391 (1974).
6. Nelson, G. O., C. A. Harder and B. E. Bigler: *Respirator Cartridge Efficiency Studies: VI. Effect of Concentration*, Lawrence Livermore Laboratory, Rept. UCRL-76134 (Nov. 1974).
7. Nelson, G. O., A. M. Correia and C. A. Harder: *Respirator Cartridge Efficiency Studies: VII. Effect of Relative Humidity and Temperature*, Lawrence Livermore Laboratory, Rept. UCRL-77390 (Aug. 1975.)
8. Smisek, M. and S. Cerny: *Active Carbon*, pp. 103-135, Elsevier Publishing Co., New York (1970).
9. Jonas, L. A. and J. A. Rehrman: Predictive Equations in Gas Adsorption Kinetics, *Carbon 11*:59 (1973).
10. Jonas, L. A. and J. A. Rehrman: The Rate of Gas Adsorption by Activated Carbon, *Carbon 12*:95 (1974).

Accepted May 12, 1975

SL 080934

EXHIBIT E

AIRBORNE CONCENTRATIONS OF ETHYLENE DIBROMIDE (EDB)
IN A GASOLINE SERVICE STATION ENVIRONMENT

Exposure to EDB in air from gasoline was tested in a service station environment at Du Pont's Petroleum Laboratory on July 17, 1975 by fueling 88 automobiles with 1577 gallons of gasoline containing 1.61g lead/gal. The fueling was performed by two operators who wore personal air monitors during the 1 hour and 50 minute operation. These monitors sampled the air at the breathing level of the operator by drawing a known volume of air through charcoal absorption tubes. Upon completion of the test, the charcoal was treated with carbon disulfide (CS_2) and the CS_2 extracts were analyzed by gas chromatography. In addition, a continuous air sample, using charcoal absorbers, was taken at a point 55 ft. up wind and at a point 35 ft. down wind of the pump island during the fueling operation. The charcoal from these air samplers was also extracted with CS_2 which was then analyzed by gas chromatography.

In addition to the charcoal air samplers, samples of ambient air were collected in previously evacuated containers and later analyzed by electron capture gas chromatography. One sample of air was taken near vehicle filler pipe during fueling, and one air sample was taken on the pump island.

The CS_2 extract of the charcoal was analyzed by gas chromatography using the same procedure recommended by NIOSH.

Results are given below:

Atmospheric EDB Concentration In Service Station Environment

89°F., 4 mph Wind from SW

Sample Site	Concentration of EDB Measured*
Up Wind	Less than 0.1ppb
Down Wind	Less than 0.1ppb
Pump Island	Less than 0.1ppb
Personal Air Monitor (Averaged over 2 hours)	Less than 0.1ppb
Vehicle Filler Pipe (5 minute grab sample)	1-2ppb

*Electron Capture Gas Chromatography.

11

UNION CARBIDE CORPORATION
CHEMICALS AND PLASTICS
P. O. BOX 8361, SOUTH CHARLESTON, W. VA. 25303

February 22, 1979

DOCKET OFFICER
DATE 3/2/79
TIME

Docket Officer, Docket H-079, Room S6212
United States Department of Labor
Third Street and Constitution Avenue, N.W.
Washington, D.C. 20210

Subject: Request for Information
Occupational Exposure to 1,2-Dichloroethane
Occupational Safety and Health Administration
(43 FR 46910)

Union Carbide Corporation, a producer and user of 1,2-dichloroethane since before 1930, desires to submit information to the Occupational Health and Safety Administration on the subject of occupational exposure to 1,2-dichloroethane as requested (43 FR 56910). Union Carbide Corporation appreciates the granting of additional time by OSHA to permit it to more fully evaluate its data and to reply more fully to the request for information. We have reacted positively to the National Institute of Occupational Safety and Health's recommendation that worker exposures to 1,2-dichloroethane be reduced to 5 ppm TWA 8 by setting an internal standard at this level; however, we do not endorse the further reduction of worker exposure now recommended by NIOSH nor do we believe that NIOSH has fully provided information in its Criteria for a Recommended Standard . . . . Occupational Exposure to Ethylene Dichloride (1,2-Dichloroethane) dated March 1976 to support its previous recommendation.

The United States Department of Health, Education and Welfare, National Cancer Institute has conducted a Carcinogensis Bioassay of 1,2-Dichloroethane by dosing rats with 95 mg/kg/day and 47 mg/kg/day and mice with 97 mg/kg/day to 299 mg/kg/day by gavage. The oral administration of ethylene dichloride caused fore stomach cancers, hemangiosarcomas of multiple organs, subcutaneous fibromas and mammary cancers in rats and breast, uterine and respiratory cancers in mice. Assuming that a 70 kilogram worker is exposed to a workplace concentration of 50 ppm for an eight hour time weighted average and that bioassay studies by ingestion can be extrapolated to inhalation exposure, then the worker's dosage would be 16 mg/kg/day or 34% of the lowest animal dosage in the study. If worker exposure is limited to 5 ppm for an eight hour time weighted average, then the dosage would be only 3.4% of the lowest rat dosage in the study, again assuming that ingestion bioassay data is directly related to inhalation and/or absorption of the material.

SL 080937

Union Carbide Corporation believes that there is an acute toxicity hazard from the high exposure of workers to ethylene dichloride via ingestion, inhalation and skin absorption and that current regulations and work practices are adequate protection from these hazards. It also does not believe that the NCI study provides any basis for NIOSH's new recommendation that worker exposures by inhalation be reduced to 1 ppm TWA 10 with a ceiling value of 2 ppm for a 15 minute sample, along with its recommendations regarding personal protective equipment and clothing.

Regarding the data on ethylene dichloride requested in the Federal Register, Volume 43, Page 56910, we have the following:

"(1) Metabolism including intermediates as well as final metabolites."

Under the management of the Manufacturing Chemists Association, Union Carbide is a cosponsor of a study of ethylene dichloride metabolism. Results of this study when completed will be made available to OSHA by MCA.

"(2) Toxicity, tumorigenicity, carcinogenicity, teratogenicity and/or mutagenicity including the effects if potential cofactors as related to each of these."

Exhibit A of this letter contains a summary of acute toxicity studies done by the Union Carbide Corporation Chemical Hygiene Fellowship at Mellon Institute of Research.

Exhibit B contains an annotated bibliography on ethylene dichloride compiled by E. I. duPont de Nemours and Company, made available through the Manufacturing Chemists Association.

A chronic inhalation toxicity study with teratology and reproduction studies managed by Manufacturing Chemists Association (Union Carbide Corporation is a co-sponsor) is underway in Dr. Cesare Maltoni's laboratory in Italy. This study involving exposure of rats to 150, 50, 10 and 5 ppm ethylene dichloride has shown no indication of carcinogenicity in preliminary results at 104 weeks. The final report is now being prepared and will be made available to OSHA by MCA when issued.

"(3) Human epidemiology (employee populations and those otherwise exposed)."

Union Carbide Corporation has made no formal epidemiological studies of exposed employee populations; there have been no indications of chronic toxicity observed in our exposed employees over the period of our manufacture and use of ethylene dichloride from the 1930's to the present day. If the National Institute of Occupational Safety and Health chooses to make such a study, our record will be made available.

"(4) Appropriate medical surveillance procedures."

Union Carbide Corporation makes medical surveillance available to its employees on a regular basis. This medical surveillance includes:

(1) A medical history

(2) A general physical examination

(3) Blood studies including a complete blood count and blood enzyme analysis

(4) Routine urinalysis

(5) Chest X-ray

(6) Pulmonary function test

(7) Vision and glaucoma tests

(8) Electrocardiograms for older employees

(9) Audiograms

Results of this medical surveillance are made available to the employee and to his personal physician if he so directs.

Union Carbide Corporation believes that its regular medical surveillance program is adequate for employee protection. Medical records are kept indefinitely. A program is under way to store and process employee medical data by computer.

"(5) Appropriate respiratory protection."

Union Carbide Corporation supplies the following respiratory equipment for employee protection:

(1) Respirator with full face piece and self-contained air supply with optional pressure demand or continuous flow modes.

These are used for emergency situations including, if necessary, entry into confined spaces.

(2) Respirator Type C with full face piece and continuous air supply from certified breathing air cylinders via hose.

These respirators are used for maintenance operations including entry into confined spaces.

(3) Respirator with full face piece and organic vapor cannister.

These cannister gas masks are used for escape purposes and for emergency situations in the open where exposure concentrations are low.

The respirator program meets the requirements of 29 CFR 1910 134. Employees are trained in their use. The respirators are regularly inspected and maintained. Respirators are cleaned and serviced after each use.

"(6) Uses and production technologies."

Union Carbide Corporation originally produced ethylene dichloride as a byproduct of ethylene glycol manufacture via the chlorohydrin process. With the development

of ethylene glycol by direct ethylene oxidation, ethylene dichloride was manufactured by the catalytic liquid phase chlorination of ethylene. This process is currently in use at UCC's Taft, Louisiana and Texas City, Texas plants. Manufacture of ethylene dichloride at UCC's South Charleston, West Virginia plant was discontinued in 1969.

Essentially all the ethylene dichloride produced at Texas City, Texas and Taft, Louisiana is converted to ethylene amines at Taft, Louisiana. Catalytic amounts of ethylene dichloride are used in organic chemical production at UCC's Port Lavaca, Texas, Ponce, Puerto Rico, Texas City, Texas and Taft, Louisiana. Ethylene dichloride was used for vinyl chloride manufacture at UCC's South Charleston, West Virginia and Texas City, Texas plants prior to 1969 when vinyl chloride production was discontinued.

> "(7) Employee exposures (actual or potential) in each use and production facility including: (a) the levels and specific conditions of such exposures, (b) the numbers of employees involved in each exposure situation."

The following tabulation shows actual UCC employee exposures as well as the numbers of employees involved. The number of employees exposed at UCC's Port Lavaca, Texas and Ponce, Puerto Rico plants where ethylene dichloride is used in catalytic quantities was not determined but it is quite small.

1,2 DICHLOROETHANE

UCC OCCUPATIONAL EXPOSURE MONITORING

LOCATIONS AND SITE	ESTIMATED NUMBER PERSONNEL EXPOSED PER MONTH	ATMOSPHERIC MEASUREMENTS											
		WORK AREA SAMPLES				PERSONNEL SAMPLES							
						ALL SAMPLES				8 HOUR TWA SAMPLES			
		NUMBER COLLECTED	CONCENTRATION IN PPM			NUMBER COLLECTED	CONCENTRATION IN PPM			NUMBER COLLECTED	CONCENTRATION IN PPM		
			GEO MEAN	ARITH MEAN	RANGE		GEO MEAN	ARITH MEAN	RANGE		GEO MEAN	ARITH MEAN	RANGE
Ponce, Puerto Rico Plant	Not Determined	22	0.35	0.35	0.35-0.35	107	0.35	0.35	0.35-0.35	45	0.23	0.29	0-0.35
Port Lavaca, Texas Plant	Not Determined	46	0.71	2.32	0.1-18.2	45	2.26	6.52	0.10-46.8	10	0.82	1.25	0.1-4.40
Texas City, Texas Plant	40	124	0.14	14.10	0-400.00	117	0.16	1.66	0-28.26	79	0.08	1.02	<0.01-14.10
Taft, La. Plant	30	156	0.62	9.18	0.04-375.70	72	0.27	2.59	0.01-83.61	47	0.19	0.28	0.05-1.20
TOTAL DIVISION		348	0.36	9.38	0-400.00	341	0.33	2.11	0-83.61	181	0.16	0.66	0-28.26

R.E.Peele/slh
2-13-79

SL 080941

"(8) Technological and economic feasibility of reducing employee exposure."

Union Carbide Corporation, in response to NIOSH's initial recommendation has set an internal standard of 5 ppm TWA 8 for exposure via inhalation. For its processes and plants this limit appears to be feasible as shown in the preceding tabulation of employee exposure and work space monitoring. The feasibility of further reduction in employee inhalation exposure would require more time for study. Based on our studies, ceiling exposure limits would pose a more serious problem than achieving low average exposures. In our closed processes, leakage, spills and equipment malfunctions more often cause employee exposure via inhalation than do normal operations.

Union Carbide Corporation, while agreeing that the NIOSH recommendations regarding protective clothing and equipment are possible, does not believe that such stringent requirements are necessary or reasonable. UCC provides impervious clothing where there is a high likelihood of skin contact with ethylene dichloride. Employees whose clothing is wetted by ethylene dichloride are discarded and replaced at no cost to the employee. The NIOSH recommendation that employees be provided with clean work clothes daily appears to be based on the unproven assumption that clothing will adsorb ethylene dichloride from the work space air.

The NIOSH recommendation that the regulated area be washed thoroughly at the end of each shift along with the absence of an action level recommendation is not feasible in UCC's plants nor do we believe it to be necessary. Such washing at frequent intervals is more likely to cause employee exposure to water bearing ethylene dichloride and is certain to make the workplace very uncomfortable and unpleasant. Where there is no mention of the subject, the term wash thoroughly implies that wipe tests will be used for monitoring. The impracticality of this test was pointed out in the testimony on the acrylonitrile standard.

In regards to employee exposure via ingestion, UCC provides clean ventilated spaces for employees to eat and the necessary facilities for washup prior to eating. There appears to be little likelihood of employee exposure via this route.

In general, Union Carbide Corporation regrets that it cannot comment more fully on this area due to the lack of definition as to what the rules governing reduction of employee exposure may be whether there will be an action level and whether there will be exemption of products containing small amounts of residual ethylene dichloride. In testimony on previous OSHA standards, we have been strong advocates of performance criteria and limits on the area where the standard is applicable. We do not believe that the specification standards recommended by NIOSH are necessary or reasonable, and they diffuse effort and increase the cost of employee protection.

"(9) Economic and technological feasibility of complying with a complete 1,2-dichloroethane standard at the lowest level of exposure feasible."

The request for information is confusing and not answerable within the time constraints imposed by the request. A complete 1,2-dichloroethane standard at the lowest level of exposure feasible must obviously be technologically feasible. Dispite the fact that OSHA states that economic feasibility cannot be used in evaluating standards, obviously if a standard is not economically feasible, then manufacture of the product being regulated will be suspended. Thus the request for information becomes a request to comment on the feasibility of a feasible standard.

After reviewing the information received as a result of this whole request, OSHA should request comments on standards involving various exposure levels. The standards for comment should clearly show the nature of the whole standard under consideration, i.e., performance versus specification, action level versus no action level, product exemption versus no product exemption.

"(10) Analytical and sampling methods used and evidence of their precision and accuracy."

The method of employee inhalation exposure monitoring used by UCC is essentially that recommended by NIOSH in its 1976 Criteria Document. Air samples are collected with activated charcoal and calibrated sample pumps, desorbed with carbon disulfide, and analyzed by gas chromatography.

Analytical methods for wipe testing are those recommended by NIOSH.

"(11) Whether issuance of an Emergency Temporary Standard is appropriate."

Union Carbide Corporation believes that issuance of an Emergency Temporary Standard is inappropriate at the present time for the following reasons:

(1) Toxicity studies in animals and humans to date show no indication that the present occupational exposure limits imposed by OSHA in 29 CFR 1910.1000 do not provide an adequate margin of safety for workers exposed to inhalation of ethylene dichloride.

(2) The National Cancer Institute study of ethylene dichloride via ingestion by gavage which indicates that it may be carcinogenic is not directly relatable to inhalation exposure and involved variable exposure, the average of which was approximately three times the dosage at the present limit set by OSHA. In any event, the NCI study involving variable dosage by gavage showed many of the cancers at the point of injection, i.e., the rats fore stomach and the respiratory tract. By any reasonable evaluation the NCI study indicates the need for further study under constant conditions instead of the obvious conclusion that ethylene dichloride is carcinogenic and should be rigidly controlled.

(3) The ethylene dichloride toxicity study sponsored by the EDC producers and managed by the Manufacturing Chemists Association is in its final report phase. This study covers metabolism, teratogenicity, reproduction study, and chronic inhalation at 150, 50, 10, and 5 ppm. The study will obviously provide data in areas where OSHA lacks knowledge, thus it would appear to be essential to the decision as to whether an ETS is appropriate. This study in a preliminary review has not shown that ethylene dichloride is carcinogenic.

(4) The NIOSH Criteria Document issued in March 1976 indicated that the primary occupational health problems resulted when employees failed to observe the OSHA limit of 50 ppm TWA 8 and when good manufacturing and work practices procedures

were not observed, i.e., handling ethylene dichloride in open buckets, using EDC as a solvent in poorly ventilated spaces and failing to remove clothing which became saturated with liquid ethylene dichloride. If OSHA chose to enforce the current regulation vigorously, the need for a new regulation would be moot.

Union Carbide Corporation appreciates the opportunity to provide information as requested by OSHA in 43 FR 56910. We are very concerned regarding the safety and health of our employees and those of our customers. We will continue to cooperate with OSHA and NIOSH in improving employee safety, however, we are concerned that new regulations may be promulgated without proper studies and careful evaluation of current regulations.

L. A. Crisorio

LAC/db

Attachments

EXHIBITS

CH_2ClCH_2Cl

Exhibit A

ngle Oral Dose, LD_{50} as 10% in Corn Oil
Rat 0.77 (0.67 to 0.89) gm./kg.
Mouse 0.91 (0.87 to 0.95) gm./kg.
Rabbit 0.91 (0.86 to 0.97) gm./kg.
ngle Skin Absorption, 1 day Rabbit Dam
LD_{50} 3.09 (3.40 to 4.46) ml./kg.
ngle Inhalation. Severe kidney injury (Spec. Rpt. 10-46; 1947)
200 ppm. 1 hr. killed 1/10 rats, 0/10 rabbits, 4/10 mice
2000 ppm. mice. 1 hr. 0/10, 2 hr. 6/10, 4 hr. 9/10
2000 ppm. rats. 1 hr. 0/6, 2 hr. 2/6, 4 hr. 12/12
6000 ppm. rabbits. 30 min. 1/4, 1 hr. 1/4, 2 hr. 4/4

-53

3264
(Replaces B-1309)

ylene Dichloride Card 1

ylene Dichloride
e also "Oxyfume" 60)

Card 2 (Spec. Rpt. 10-13; 1947 unless noted)

peated Inhalation by Rats
Daily inhalation results in death from lung injury, a form of damage not affecting humans and therefore irrelevant.
Exposure on alternate days. 75 exposures to 200 ppm. produced less injury than 100 ppm. trichloroethane, more than 200 ppm. propylene dichloride
ary Irritation, Rabbit Belly Vesicant Test (Monthly Rpt. 1-31-42)
Grade 2. Undiluted gives a trace of erythema (too volatile for this test)
ary Irritation, Rabbit Belly 4-Hour Test (No report)
Grade 1 (Score of 3)
Injury from Fluid to Rabbits (Spec. Rpt. 9-11; 1946)
Grade 3. 0.05 ml. severe, 0.1 ml. minor injury

-53

3265
(Replaces B-1310 and B-1313)

lene Dichloride Card 2. SL 080946

MANUFACTURING CHEMISTS ASSOCIATION

1825 CONNECTICUT AVENUE, N.W. WASHINGTON, D.C. 20009 (202) 483-6126

December 26, 1974

TO: Ad Hoc Planning Group on Ethylene Dichloride (EDC)

SUBJECT: Literature Survey on EDC

Gentlemen:

Dr. R. S. Waritz has kindly made available an annotated bibliography on EDC, compiled by E. I. du Pont de Nemours & Company. A copy is attached for your information and files.

Sincerely,

M. Freifeld

M. Freifeld, Secretary
Ad Hoc Planning Group on EDC

MF:meh

enclosure

RECEIVED
JAN 6 1975
H. R. GUEST

1,2-DICHLOROETHANE
(ETHYLENE DICHLORIDE, EDC)

Chem Toxicity List
Usual ref. books
Haskell Lab Files

I. ACUTE TOXICITY

A. Oral

a) Values

human	LD_{LO}*	845 mg/kg	(1)
	LD_{100}	56 ml	(3)
rats	LD_{50}	680 mg/kg	(1)
	LD_{50}	680-770 mg/kg	(3)
	LD_{50}	770 mg/kg (670-890)	(4)
mice	LD_{LO}	600 mg/kg	(1)
	LD_{50}	910 mg/kg	(3)
dogs	LD_{LO}	2,000 mg/kg	(1)
	LD_{100}	2,500 mg/kg	(3)
rabbits	LD_{50}	910 mg/kg	(3)

Isomer unspecified:

dog	LD_{50}	1.3 ml/kg	(2)
	LD_{100}	1.9 ml/kg	(2)
guinea pig	LD_{50}	0.6 ml/kg	(2)
	LD_{100}	1.2 ml/kg	(2)
rabbits	LD_{50}	0.8 ml/kg	(2)
	LD_{100}	1.6 ml/kg	(2)
rats			
young	LD_{50}	1,135 ± 70 mg/kg	(12)
	LD_{100}	2,000 mg/kg	(12)
adult	LD_{50}	625 ± 50 mg/kg	(12)
	LD_{100}	1,500 mg/kg	(12)
senile	LD_{50}	560 ± 38 mg/kg	(12)
	LD_{100}	1000 mg/kg	(12)

* Specific gravity 1,1-Dichloroethane = 1.776
1,2-Dichloroethane = 1.256

LD_{LO} = lowest lethal dose
LD_{100} = lethal dose to 100% of test animals
LD_{50} = lethal dose to 50% of test animals

A. Oral (Continued)

mice			
young	LD_{50}	1,308 ± 79 mg/kg	(12)
	LD_{100}	3,000 mg/kg	(12)
adult	LD_{50}	1,120 ± 192 mg/kg	(12)
	LD_{100}	2,500 mg/kg	(12)
senile	LD_{50}	725 ± 38 mg/kg	(12)
	LD_{100}	1,500 mg/kg	(12)

b) Effects

Isomer unspecified:

rats 1-2 ml/kg death at 10-16 hours
Results: bradycardia, bradypnea, total atrioventricular block, cessation of respiration, due to "action on the central nervous system and in particular the respiratory centers." (28)

rats 1.0 ml/kg
rabbits 0.5 ml/kg
Results:
- 24-72 hours: "reversible dystrophic changes in the liver"
- 4-5 days: decrease in fat content of hepatocytes, appearance of cells with 2-3 nuclei
- 6-8 days: necrotic foci disappeared (31)

rats 0.7 ml/kg
Results: decreased rate of oxidative phosphorylation in liver mitochondra (32)

rabbits 1.2 ml/kg
Results: marked increase in fibrinogen content of the blood, acceleration of clotting reaction (41)

rabbits 0.9 - 1.7 ml/kg
Results: toxic pulmonary edema, "accompanied by a series of changes in the blood." (42)

B. Skin

a) Absorption

rabbit	LD_{50}	3890 mg/kg	(1)
	LD_{50}	3.89 ml/kg (3.40-4.46)	(4)
	LD_{50}	2,800 mg/kg	(3)

B. Skin (Continued)

Isomer unspecified:

rabbits 10 mg/l in air
Results: decreases respiration and glycolysis, and cytochromic oxidase in red blood cells, caused a decrease in activity of serum enzymes, including cholinesterase, affects membrane permeability of renal cells. (29)

b) Irritation

rabbits Score 2* - "trace of capillary injection" (4)

C. Eye

rabbit Score 3* (4)

dog corneal opacity (16)

D. Injection

a) Subcutaneous

rats	LD_{50}	500 mg/kg	(1)
	LD_{50}	1,000 mg/kg	(3)
mice	LD_{LO}	380 mg/kg	(1)
rabbits	LD_{LO}	1,200 mg/kg	(1)
	LD_{100}	1,600 mg/kg	(3)

b) Intraperitoneal

rats	LD_{50}	600 mg/kg	(1)
mice	LD_{LO}	250 mg/kg	(1)
	LD_{50}	470 mg/kg	(6)

c) Intravenous

dog	LD_{LO}	175 mg/kg	(1)
	LD_{100}	175 mg/kg	(3)
	LD_{100}	0.25 ml/kg	(5)
	LD_0	0.125 ml/kg	(5)
mice	0.075 ml/kg	10% increase in urine protein	(34)
	0.2 ml/kg	30% increase in urine protein	(34)
	0.4 ml/kg	56% increase in urine protein	(34)

* Skin irritation scores run from 0 (no effect) to 10 (necrosis)
Eye irritation scores run from 0 (no effect) to 20

L. Inhalation

1 mg/l = 247 ppm and 1 ppm = 4.05 mg/m^3 at 25°C, 760 mm Hg

a) Values

humans	TC_{LO}			4,000 ppm (1)
rats	LC_{LO}	4 hours		1,000 ppm (1)
	LC_{50}			1,000 ppm (3)
	maximum time survived		12 min.	20,000 ppm (8,10)
			1 hour	3,000 ppm (8,10)
			7 hours	300 ppm (8,10)
	no effect times		6 min.	12,000 ppm (8,10)
			1.5 hours	1,000 ppm (8,10)
			7 hours	200 ppm (8,10)
mice	LC_{100}			9,000 ppm (3)
rabbits	LC_{LO}	7 hours		3,000 ppm (1)
	LC_{LO}	unspecified		1,000 ppm (7)
guinea pigs	LC_{LO}	2 hours		9,000 mg/m^3 (1)
	LC_{100}			3,000 ppm (3)
pigs	LC	7 hours		3,000 ppm (1)
rats	LC_{50}	0.53 hours		12,000 ppm (8)
	LC_{50}	2.75 hours		3,000 ppm (8)
	LC_{50}	7.20 hours		1,000 ppm (8)
	LC 0.01*	0.23 hours		12,000 ppm (8)
	LC 0.01	1.02 hours		3,000 ppm (8)
	LC 0.01	3.70 hours		1,000 ppm (8)
	no effect level	0.1 hours		12,000 ppm (8)
		0.3 hours		3,000 ppm (8)
		1.5 hours		1,000 ppm (8)
	lethal dose	"few minutes"		150,000 ppm (9)
	deep narcosis	30 minutes		12,000 ppm (9)
	slight symptoms	8 hours		1,000 ppm (9)

TC_{LO} = lowest toxic concentration
LC_{LO} = lowest lethal concentration
LC_{50} = concentration lethal to 50% of test animals
LC_{100} = concentration lethal to 100% of test animals
$LC_{0.01}$ = concentration lethal to 0.01% of test animals

b) Effects

rats, guinea pigs, rabbits, monkeys 100-400 ppm 7 hours
Results: "depression of the central nervous system, lung irritation, and organic injury of the liver, the kidneys, and the adrenal glands." (8)

rabbits 300 ppm time unspecified
Results: no significant changes in the blood and spinal marrow, with the exception of "toxic granulation in granulocytes of about 20%." (24)

rabbits levels and time unspecified
Results: liver damage, kidney lesions, and "less marked degenerative signs in other organs." (25)

Isomer unspecified:

rats 10 mg/l 4 hours
Results: decrease in cholinesterase activity
serum: 37-43% decrease
plasma: 23% decrease
brain: 16.4% decrease
spinal cord tissues: 16.7% decrease
liver: 27.8% decrease
pancreas: 20.3% decrease
heart: 29% decrease
pylorus: 31.2% decrease (33)

CHRONIC TOXICITY

A. Oral

cows 100 ppm 22 days
500ppm, 10 days then 1000 ppm, 12 days
Results: no loss of appetite, no decrease in milk production (13). Levels of 1000 ppm produced concentrations of less than 0.25 ppm in the cow's milk (14).

Isomer unspecified:

rats fed maize, sugar beets treated with 0.1-0.5% EDC time unspecified
Results: no change in blood composition or liver function (30)

B. Inhalation

a) Spencer, et. al. (8,15)

400 ppm

rats	up to	40	7 hour exposures
guinea pigs	up to	24	7 hour exposures
Results:		no survivors, no tumors, increased liver and kidney weights, histological changes in liver and kidney	
rabbits		165	7 hour exposures
Results:		maximum for no effect	

200 ppm

rats	157	7 hour exposures
Results:	maximum for no effect	
guinea pigs	180	7 hour exposures
Results:	histological changes, no tumors	

100 ppm

rats, male	115	7 hour exposures
, female	142	7 hour exposures
guinea pigs, male	121	7 hour exposures
, female	162	7 hour exposures
rabbits	178	7 hour exposures
monkeys	148	7 hour exposures
Results:	no adverse effect "The significant chronic effect appears to be hepatic... and/or renal damage." (8)	

b) Heppel, L. A. et. al. (17)

1000 ppm	7 hours/day	5 days/week	
guinea pigs	survived 2 exposures		
rats	survived 3-14 exposures		
rabbits	survived 2-64 exposures		
dogs, cats, monkeys	23-55 days	low mortality	
Results:	fatty changes in liver		

400 ppm	7 hours/day	5 days/week	
rats, rabbits, guinea pigs		high mortality	
Results:	liver damage		
dogs	survived 177 exposures		

b) Heppel, L. A. et. al. (Continued)

200 ppm

rats		125 exposures	
	Results:	greater than normal mortality, mild pulmonary congestion	
guinea pigs		125 exposures	
	Results:	greater than normal mortality, histological changes	
rabbits		125 exposures	no effect
monkeys		125 exposures	no effect

100 ppm

rats survived "many" experiments; no lesions
guinea pigs
monkeys

c) rats, guinea pigs, rabbits, cats 6 hour/day 5 days/week
500 ppm toxic to all in 13 weeks
100 ppm tolerated for 17 weeks (19)

d) rabbits levels unspecified "chronic poisoning"
Results: most severe damage in liver, decrease in lipids of leukocytes, kidney degeration and necrosis, deterioration of kidney function. (25)

e) rabbits 0.6 - 0.15 ml/kg/hour
Results: "bradycardia,...cardiac excitability, and a progressive decrease in the blood pressure to death." (23)

f) rabbits 3000 ppm "chronic exposure"
Results: "A direct poisoning effect on the bone marrow is concluded." (24)

Isomer unspecified:

g) rats 5 mg/l 3.5 months
Results: changes which "reflect pathological excitation followed by decreased functional activity of the entire central nervous system." (18

h) rats .05 - .01 mg/l 3-5 hours/day
Results: changes in conditioned reflexes histological changes in the brain. Both disappeared when removed from exposure. (22)

i) rabbits 2 mg/m^3 3 hours/day 8-10 months
Results: did not affect antibody formation (20)

changes in liver and kidneys (21)

rabbits 10 mg/m^3 3-4 hours/day 7-11 months
Results: "not toxic" (21)

k) rats 5 mg/m^3 4 hours/day 1-9 months

rats 3 mg/m^4 and 120 mg/m^3 gasoline
4 hours/day 1-9 months
Results: "considerable changes of the estrus cycle and its periodicity," a decrease in total number of cycles, number of leukocytes and phagocytic activity not affected (27)

l) rats 30 mg/m^3 plus 1210 mg/m^3 gasoline vapors
4 hours/day 6 mos. prior to and during pregnancy
Results: "changes in duration of estrus cycle," decrease in fertility, weight, and muscle efficiency of neonates, increased lethality in progeny, no abnormalities in following generation (26)

I. ADDITIONAL EFFECTS

A. Mutagenicity

a) wheat seeds 1 ml for 1 day
Results: 0.3% dominant mutations
1.8% recessive mutations (35)

b) Drosophila melanogaster 0.07% 4-8 hours
Results: increased number of recessive mutations and occurrence of non-divergence of X-chromosome. (36)

c) Drosophila melanogaster levels and time unspecified
Results: increased frequency of recessive lethal mutations, no influence on non-divergence of chromosomes in radioresistant organisms (37)

d) Drosophila melanogaster levels unspecified
Results: 1 day treatment: 25-30% mutations, more pronounced in males
1 hour treatment: 2.6% mutations (38)

B. Other organisms

a) Invertebrates in water 0.1 mg/l
maximum concentration for "normal biological activity" (39)

b) maize prolonged storage with EDC in tropics may affect seedling growth (40)

c) 0.455M kills Vibrio (bacteria)
0.065M prevents fermentation of sugar by yeast (5)

Isomer unspecified:

d) marine pinperch TLm* 150-175 mg/l

e) mole crickets 150 ml/m^2
Results: effective in controlling these insects (43,

f) spore-forming bacteria, molds 300 g/m^3
Results: no molds developed, spore-forming bacteria developed normally (48)

IV. METABOLISM

a) readily absorbed from the gastro-intestinal tract or the lungs, absorbed to a lesser extent from the skin (10)

b) mice 0.05 - 0.17 g/kg injected intraperitoneally
10-45% expired unchanged
12-15% expired as CO_2
51-73% urine
0-0.6% feces
0.6-1.3% remaining

Major metabolites:
S-carboxymethylcysteine
thiodiacetic acid
chloracetic acid

Minor metabolites:
2-chloroethanol
S,S'-ethylene bis cystein (45)

c) rats route and dose unspecified
Major metabolite in urine:
N-acetyl-S-(β-hydroxyethyl) cysteine
Secondary metabolite:
S-(β-SS-hydroxyethyl) cysteine (46)

SL 080956

*TLm = median threshold limit

N TOXICITY

"Ethylene dichloride is toxic by inhalation, by contact skin or mucous membranes, or by oral intake. Prolonged sive, or repeated exposures to the product in any form are ardous. The signs and symptoms of excessive absorption to be ched are: headache, mental confusion, depression, fatigue, s of appetitie, nausea, vomiting cough, loss of sense of balance, visual disturbances. There may also be diarrhea with bloody ols, suppression of urine, swelling of face, jaundice, and od in the urine." The signs and symptoms of EDC poisoning the result of injury to the kidneys, adrenal glands, skin, gs, and to the digestive and nervous system. The clinical picture ies with the type of exposure and the amount of the chemical oduct which is absorbed, either at one or at repeated times." (54)

Oral

Patty (10) states that EDC "does present a problem from al ingestion," as evidenced by the number of poisoning fatalities see below). Effects include CNS depression, gastrointestinal ritation, increase in clotting time, and injury to liver, kidneys renals, and lungs.

Should an ingestion occur, vomiting should be induced and psom sales administered. (54)

Skin

a) Irritation and sensitization

If held close to the skin EDC can cause severe irritation with moderate edema and necrosis (10). Repeated or prolonged contact "may cause a rough, red, dry skin due to extraction of fatty materials" (10). "In certain rare cases, the dermatitis may be caused by hypersensitivity to ethylene dichloride" (54,55).

Should skin contact occur, remove all contaminated clothing, wash the area well and apply an ointment containing lanolin. (54)

b) Absorption

EDC can be absorbed through the skin, although "it takes quite large doses to cause serious systemic poisoning." (10)

C. Eye

This chemical and its vapors can cause irritation, burning, and lachyrimation. Serious damage can occur if the substance is not removed promptly. Exposed eyes should be washed with water for 15 minutes. (10,54)

D. Inhalation

Symptoms of both actue and chronic vapor poisoning are irritation of the eyes, nose, and throat, headache, mental confusion, dizziness, and vomiting. EDC "has the ability to cause injury to the liver and kidney from eith excessive single or repeated exposures" (56). Borisova reports that concentrations greater than 6 mg/m^3 "cause vasoconstriction, decreasing light-sensation of the eyes, and reflex changes in rate, depth, and rhythm of respiration." (11)

In the event of overexposure to EDC, remove the subject immediately and do not administer adrenalin. (54)

E. Threshold

a) Single Exposures - not more than once a week

7 hours	200	(56)
1 hour	1,000	(56)
0.1 hour	2,000	(56)

b) Repeated Exposures

Threshold Limit Value (ACGIH)	50 ppm (200 mg/m^3)	(1)
Ceiling Value	50 ppm	(56)
	100 ppm	(1)
Peak Value (not more than 5 min. not more than one in 3 hours for an 8 hour day)	200 ppm	(1)
Recommended Russian Threshold	1 pp,	(11)

c) Odor Levels

50 ppm	barely detectable	(10)
100 ppm	not unpleasant	(10)
200 ppm	pronounced, not unpleasant	(10)
8.5ppm 17.5 mg/m^3	detected only by those with acute sense of smell	(11)
$mg/m^3 = 0,25ppm$ 23.2 mg/m^3 6 ppm	average level of detection	(11)

23 / 5 / 15 / 5

The odor of EDC is sweetish and can be adapted to at lower levels; therefore, it is "probably not sufficiently striking to be considered a significant warning of hazardous chronic exposure." (10)

F. Poisoning

8 / 25 / 50 / 50

Several cases of EDC poisoning have been reported in the literature. "The late appearance and non-specificity of the clinical symptoms and signs" is characteristic of such cases, causing one author to warn that "lack of symptoms even several hours after ingestion or inhalation should not be taken as a reassuring sign." (51)

pathological changes in nervous system observed
24 hours after infusion-diuresis treatment: normalization of EEG

b) 14 year male — ingested 15 ml (for intoxication)
Symptoms: 2 hours: headache, staggering, vomiting
6 days: died
Autopsy: liver necrosis and resultant hypoglycemia, increase in clotting time, renal failure, and hypercalcemia. (51)

c) ingestion 2 oz.
Symptoms: 2 hours: nausea, faint
5 hours: dazed
22 hours: cyanosis, death (5)

d) 18 year male — ingested 50 g (suicide)
Effects: death at 18 hours, "basically caused by generalized intravascular clotting accompanied by irreversible shock."
Autopsy: "intense necrotic and hemorrhagic enteritis, widespread erosion of the intestinal mucosa and petechial bleeding subendocardially and supercardially in the kidneys and in the bladder epithelium." (52)

e) Poisoning victims — isomer, amount, route unspecified
Autopsy: renal failure, swelling and protein dystrophy in tubular epithelium, decrease in glomerular DNA and RNA. (47)

f) Worker treating grains with Granosan (70% EDC, 30% carbon tetrachloride)
Effects: died with "severe lesions in liver and kidneys"

g) Worker — inhalation — levels unspecified
Effects: fatal, hyperemia and edema of lungs, degenerative changes of kidney, damage to liver and adrenals. (14)

h) 27 workers — inhalation
Effects: non-fatal, CNS depression, semiconsciousness, and hepatorenal syndrome. (57)

i) Russian plane factory using EDC
Effects: number of cases of illness, mostly intestinal and nervous disorders, and number of days lost due to illness were 100% greater in departments using EDC than in rest of the plant.

j) Russian factory — inhalation (isomer unspecified)
Effects: "chronic hepatitis, chronic gastritis, dystrophy of the myocardium, astenovegetative syndrome, vegetative polyneuritis, and allergy." Polyethylene polyamine had synergistic effects with EDC. (55)

1. The Toxic Substances List (1974).
2. Kagramanov, B. G. Azerb. Med. Zh. 49(7):65-8 (1972). In Azerbaijanian, English Summary from Chemical Abstracts (CA78:53578m).
3. World Health Organization Summary (1970):C-0951.
4. Smyth, H. F. et. al. Am. Ind. Hyg. Assn. J. 30(5):470-6 (1969).
5. Von Oettingen, W. F. J. Ind. Hyg. Tox. 19(8):349-436 (1937).
6. Baganz, H. et. al. Arzneimittel-Forsch. 11:902-5 (1961). Summary from Chemical Abstracts (CA56:6309d).
7. The Toxic Substances List (1973).
8. Spencer, H. C. et. al. A.M.A. Arch. Ind. Hyg. Occup. Med. 4:482-93 (1951).
9. MR 13-121.
0. Patty, F. A. Industrial Hygiene and Toxicology, Vol. II (1963), p. 1280-4.
1. Borisova, M. K. Gig. Sanit. 22(3):13-19 (1957). Summary from Chemical Abstracts (CA51:12384f).
2. Savchenko, M. F. Gig. Sanit. 32(3):31-5 (1967). English translation p. 349-54.
3. Sykes, J. F. and A. K. Klein J. Assoc. Offic. Agr. Chemists 40:203-6 (1957). Summary from Chemical Abstracts (CA51:5320d).
4. "Evaluation of the Hazards to Consumers Resulting from the Use of Fumigants in the Protection of Food." FAO (1965).
5. Shubik, P. and J. L. Hartwell Survey of Compounds Which Have Been Tested for Carcinogenic Activity PHS 149 Supplement I (1957), p. 48.
6. Heppel, L. A. et. al. A.M.A. Arch. Opthamol. 32:391 (1944).
7. Heppel, L. A. et. al. J. Ind. Hyg. Tox. 28:113 (1946).
8. Dmietrieva, N. V. et. al. Gig. Sanit. 36(4):20-5 (1971). Summary from Chemical Abstracts (CA75:18022s).
9. Hofmann, H. Th. et. al. Arch. Toxikol. 27(3):248-65 (1971). In German, English summary from Chemical Abstracts (CA75:61562e).
0. Shmuter, L. M. Gig. Sanit. 37(2):36-40 (1972). In Russian, English summary from Chemical Abstracts (CA76:149673y).
Navrotskii, V. K. et al. Tr. S'ezda Gig. Ukr. SSR, 8th 1970 (Pub. 1 224-6. In Russian, English summary from Chemical Abstracts (CA77:71060
2. Tolgskaya, M. S. Gig. Sanit. 27(2):8509 (1962). In Russian, English summary from Chemical Abstracts (CA57:1223f).
3. Loscalzo, R. et. al. Lavoro umano 11:554-66 (1959). Summary from Chemical Abstracts (CA55:26234b).
4. Lioia, N. et. al. Folia. Med. 42:1233-54 (1959). Summary from Chemical Abstracts (CA54:4908f).
5. Lioia, N. et. al. Folia. Med. 42:1400-8, 1524-57 (1959). Summary from Chemical Abstracts (CA54:13433 e,f,g.h).
6. Vozovaya, M. A. Akush. Ginekol. 1973(9):66-8. In Russian, English summary from Chemical Abstracts (CA80:34236y).
7. Vozovaya, M. A. Akush. Ginekol 47(12):65-6 (1971). In Russian, English summary from Chemical Abstracts (CA77:29874p).
8. Saitanov, A. O. et. al. Gig. Tr. Prof. Zabol. 13(7):49-50 (1969). In Russian, English summary from Chemical Abstracts (CA71:121894u and (CA73:107695q).
9. Petrun, N. M. et. al. Farmakol. Toksikol.30(3):356-8 (1967). In Russi English summary from Chemical Abstracts (CA67:52291y).
0. Vorob'eva, N. M. Vop. Ratsion. Pitan. 1969(5):123-6. In Russian, English summary from Chemical Abstracts (CA73:65416s).

SL 080960

1. Chernukha, F. S. Farmakol. Toksikol. 1973(8):148-50. In Russian, English summary from Chemical Abstracts (CA80:128950d).
2. Natysuk, M. V. et. al. Farmakol. Toksikol. 37(1):92-3 (1974). In Russinan English summary from Chemical Abstracts (CA80:128965n).
3. Slyusar, M. P. Voor. Gig. Tr. Prof. Zabol. Gornorudn., Khim. i Mashinostroitel. Prom. Sbornik p. 92-100 (1958). In Russian, English summary from Chemical Abstracts (CA53:5506c).
4. Ploa, G. L. and R. E. Larson Tox. Appl. Pharm. 7:37-44 (1965).
5. Kozhanova, N. N. and N. N. Zoz Agrokhimiya 1966(11):123-4. In Russian, English summary from Chemical Abstracts (CA66:8872x).
6. Sakarnis, V. Genetika 5(12):89-95 (1969). In Russian, English summary from Chemical Abstracts (CA72:129677s).
7. Sakarnis, V. Vestn. Leningrad. Univ. Biol. 1970(1):153-6. In Russia English summary from Chemical Abstracts (CA73:32801k).
8. Rapoport, I. A. Doklady. Akad. Nauk. S.S.S.R. 134:1214-17 (1960). In Russian, English summary from Chemical Abstracts (CA55:8675h).
9. Lobacheva, L. L. Rybnoe. Khoz. 33(7):71-4 (1957). English summary from Chemical Abstracts (CA51:18355e).
0. Caswell, G. H. et. al. Empire J. Exptl. Agr. 26:365-72 (1958). Summary from Chemical Abstracts (CA53:9554i).
1. Kagramanov, B. G. et. al. Uch. Zap. Azerb. Med. Inst. 36:30-31 (1971) English summary from Toxline.
2. Kagramanov. B. G. Azerb. Med. Zh. 47(3):79-81 (1970). In Pussian, English summary from Toxline.
3. Vinnichenko, I. F. Tr. Kishinev. Sel'zkokhoz. Inst. 88:90-2 (1972). In Russina, English summary from Chemical Abstracts (CA79:1328).
4. Vinnichenko, I. F. Tr. Kishinev. Sel'skokhoz. Inst. 66:182-91 (1971): In Russian, English summary from Chemical Abstracts (CA79:1304).
5. Yllner, Sven. Acta. Pharmacol. Toxicol. 30(3-4):257-65 (1971). Summary from Chemical Abstracts (CA76:68867n).
Alumot et. al. Fate of Pesticides in Env., Gor. (1972), p.495-501.
. Kamenko, V. M. Vrach. Delo. 1973(11):72-7. In Russian, English summary from Chemical Abstracts (CA80:104584m).
. Pod'yapol'skaya, O. P. Tr. Vses. Nauchn.-Issled. Inst. Zerna i Produk ego Pererabotki No. 43:69-93 (1963). English summary from Chemical Abstracts (CA61:7633f).
. Secchi, G. C. and L. Alessio Epatologia 17(3):279-89 (1971). In Italian, English summary from Chemical Abstracts (CA77:135890a).
. Winkel, G. K. et. al. Kinderaerztl. Prax. 37(5):209-16 (1969). In German, English summary from Toxline.
. Yodaiken, Ralph E. et. al. Arch. Env. Health 26(5):281-4 (1973).
. Schoenborn, H. et. al. Klin. Wochshr. 48(13):822-4 (1970).
. Guarino, A. and N. Lioia Folia. Med. 41:676-90 (1958). English summary from Chemical Abstracts (CA53:576g).
. Chemical Safety Data Sheet SD-18 (1947) (C-951).
. Voshchinina, G. I. et. al. Mater. Konf. Molodykh. Nauch. Rab. Nizhnego Tagila, Med. Sekts., 2nd, p. 18-20 (1969). In Russian, Englis summary from Chemical Abstracts (CA78:7459a).
. Torkelson, T. R. et. al. Pest Control 34(7):13-18, 42-50 (1966).
. Chenoweth, M. B. et. al. Ann. Rev. Pharm. 2:363-98 (1962).
. Kozik, I. V. Gig. Tr. Prof. Zabol. 1(1):31-8 (1957). In Russian, English summary from Chemical Abstracts (CA51:9974d).
. McKee, J. E. et. al. Water Quality Criteria 2nd ed. (1963), p.178.

12

Diamond Shamrock

Law Department - Chemicals

DOCKET OFFICER
DATE 3/5/79
TIME

March 2, 1979

Docket Officer
Docket No. H-079
Rm. S-6212
U. S. Department of Labor, OSHA
Third St. and Constitution Ave., N.W.
Washington, D.C. 20210

Re: 1,1-Dichloroethane (ethylene dichloride)

Gentlemen:

Supplementing our letter of February 2, 1979, we herewith submit data and comments in response to your request of December 5, 1978 (43 Federal Register 56910) regarding the desirability of reducing the present exposure limit on ethylene dichloride.

Diamond Shamrock's Electro Chemicals Division produces ethylene dichloride (EDC) as a precursor for other solvents and markets it primarily for use as a metal cleaning solvent. Our Plastics Division produces EDC as an intermediate in the production of vinyl chloride monomer (VCM), and our Process Chemicals Division uses ethylene dichloride in the manufacture of various specialty chemicals.

1. Exposure Data

Diamond Shamrock produces EDC at two plants, both located in the Houston, Texas area. In our Independence VCM Plant, EDC produced from the reaction of chlorine and ethylene is cracked to form VCM and hydrogen chloride. The VCM is stored for shipment to customers or to our own PVC production facilities nearby. The by-product hydrogen chloride is combined with ethylene in an oxyhydrochlorination process to form more EDC, which is then used to produce more VCM. At our Deer Park Solvents Plant, EDC is produced by direct chlorination of ethylene and by the oxyhydrochlorination process.

SL 080962

Exhibit 1 describes EDC exposures at our VCM plant during the period June 1 through December 31, 1978. It shows exposures of administrative, laboratory, production and maintenance workers in terms of eight-hour time-weighted averages, the individual employee's job classification, and the number of samples taken.

Exhibit 2 describes exposures at our Deer Park Solvents Plant during the period February 1, 1976 through September 30, 1978. These eight-hour time-weighted averages were developed by our statistical environmental monitoring program, first implemented in February of 1976. Under our program, we cannot break down the daily time-weighted averages to determine the minimum and maximum exposure levels or the duration of such levels. It should be noted, however, that the highs reported in Exhibit 2 are attributable to leaks which were promptly detected and repaired.

We presently have only preliminary exposure data from our two plants which use EDC in the manufacture of specialty chemicals, but we are continuing to monitor at both. Thus far, exposures at both plants have been found to be within the limits specified in 29 CFR 1910.1000.

Comparison of Exhibits 1 and 2 shows that VCM Plant exposures are much lower than those at the Solvents Plant. In the former, the eight-hour time-weighted averages are seldom over 1 ppm. In the latter, monthly averages are generally below 5 ppm, but they are seldom below 1 ppm, and there are occasional excursions. These differences are explained by the fact that the Independence VCM Plant, completed in early 1978, incorporates the latest technology and was designed to meet or exceed current governmental emission control and exposure requirements. The exposures are the result of "fugitive" emissions (i.e., those emissions remaining after the imposition of controls). In effect, the VCM plant is a closed system. In contrast, the direct chlorination and oxyhydrochlorination facilities of the Solvents Plant were built in 1957 and 1967 respectively, before current exposure and emission controls were conceived or employed in the industry. They are not closed systems, and it would require a very substantial and uneconomical investment to enclose them.

2. Toxicology

Diamond Shamrock had three short-term toxicological tests performed on EDC by Bio-Tox Laboratories, Spencerville, Ohio. The three tests were an Ames test, a host-medicated assay and a dominant lethal test. These screening tests are qualitative indicators of possible mutagenicity. Copies of the test data are enclosed as Exhibit 3. The Ames test and host-mediated assay indicated no mutagenic activity for EDC. The Ames test result is of questionable value, since there is no way to verify whether the EDC evaporated during the 48-hour incubation period the test requires. The dominant lethal test indicated that, for a single dose exposure, there were no observable effects. In the subacute administration (5 days), however, there were fewer embryos.

We believe you are familiar with the various toxicological studies being conducted under the auspices of the Manufacturing Chemists Association. We are a participant in those studies and expect that they will determine the significance of effects observed in the above-mentioned dominant lethal test.

MCA chose inhalation studies to provide a more reliable indication of teratological and reproductive effects than a repetition of the dominant lethal tests would have provided, since inhalation represents the most common means of human exposure. The inhalation tests are of longer duration and greater sophistication and so provide a much better indication of biochemical behavior.

We believe it would be only prudent for the agency to postpone any action on EDC until completion of the very substantial program of studies undertaken by MCA. Certainly, to initiate a rulemaking with only the somewhat dated NCI data would appear wholly unwarranted in the absence of any other evidence that EDC presents a hazard.

3. Reduction of Exposure Levels

Roughly 80 percent of U. S. production of EDC goes to make VCM. To the extent that our VCM plant exposures are typical,

it would appear that very low levels have already been achieved by that segment of the industry. This is probably due to the fact that VCM is produced in a closed system either in new plants, or in plants substantially modified to comply with OSHA and EPA regulation of VCM exposures, as well as FDA requirements.

On the other hand, our Solvents Plant is somewhat typical of plants producing EDC for non-VCM end uses. It is much older and is not enclosed. Because of its age, some major items of equipment would probably have to be replaced because the would not be adaptable to modern control techniques.

We wish to note that we have under way a number of project the effect of which will be to reduce levels of exposure t: EDC at our Solvents Plant. These include the conversion f: open-top dryers to closed vessels and the use of a new type of product filter which would eliminate personnel exposure while changing cartridges. We also have under way a new waste water treatment facility which will enable us to eliminate our sump, a substantial source of EDC emissions for us. In addition, we are installing an enclosed process sewer in our perchloroethylene process area.

As we see it, the question is not whether the exposure level can be reduced, but whether it ought to be reduced by regulation at this time. Nevertheless, we have made an analysis to determine the feasibility and cost of additional steps to further reduce Solvents Plant EDC exposures. We see no purpose in submitting that information at this time given the lack of evidence warranting a reduction. Our analysis makes clear, however, that, while such reduction may be feasible, its cost (we estimate it at $5 million to $10 million) would raise serious questions about the profitability of continuing the operation.

4. Epidemiology

We are not able to include epidemiological data with this submission. However, we have undertaken a project of correlating medical data of our Solvents Plant employees with EDC exposure data for the years 1975 through 1978.

In over 20 years of operation, during which over a million tons of EDC were produced, we have observed no detrimental effect upon employee health as the result of EDC exposure. This has continued to be the case, since the inception of our medical surveillance program several years ago. Accordingly, we would expect that this project will demonstrate that there is no correlation between EDC exposure and adverse health effects.

5. Appropriateness of Emergency Temporary Standard

Clearly, there is no reason to issue an Emergency Temporary Standard under Section 6(c). To do so, the Secretary must first determine that employees are exposed to "grave danger" from exposure to substances determined to be toxic and that an emergency temporary standard is necessary to protect employees from such danger. In our view, neither element of that test is met by data currently available.

The National Cancer Institute studies referred to in the Agency's December 5, 1978 request do not establish the existence of a human hazard. The MCA-administered studies mentioned above, while not complete, appear to suggest that EDC is not an animal carcinogen, mutagen or teratogen. The Bio-Tox studies conducted at our request also did not demonstrate these effects. Accordingly, if animal data can be said to indicate human risk, we believe these tests do not indicate it. In fact, they fail to demonstrate that EDC is even an animal carcinogen.

We are aware of the dangers in relying on negative epidemiological data. However, it is not a question here of whether such data should be allowed to offset positive animal data. In the absence of replicated animal studies, considerable weight must be given to the substantial data suggesting that chlorinated solvents have not been shown to cause disease in man.

Chlorinated solvents exhibit a relatively consistent toxicological response (e.g., potency, dose and type of effect) within a strain of bacteria or animals, but these results cannot be extrapolated to predict the response of another strain of bacteria or animal, much less the response of human beings.

Some of the chlorinated solvents have been shown to be weak bacterial mutagens and weak animal carcinogens. If one excludes the B6C3F1 mouse, however, these chemicals do not generally elicit a carcinogenic response in the wide variety of animals which have been employed in the toxicology bioassays funded either by the chemical industry or the National Cancer Institute.

The available human epidemiological data, including those reviews contained in the NIOSH Criteria Documents, show no case of human cancer caused by exposure to any one of these chlorinated solvents.

The lack of cancer induction by these common solvents becomes critically significant when it is understood (a) that they have been in production for nearly half a century, far beyo the required latency period for cancer induction, (b) that the production volume has long been over a million tons annually, (c) that distribution of these materials is worldwide, and (d) that exposure controls have only recently been established. This means that, with millions of man-years of exposure to the chlorinated solvents, there is no evidence that they have caused cancer. In addition, recent governmental studies designed to establish whether the presence of chlorinated solvents in public drinking water presented significant health hazards found no evidence of cancer or other human diseases. Surely this lack of evidence cannot be disregarded.

From the foregoing, one must conclude that lowering the present exposure limit for EDC will neither alter nor improve the health of exposed employees. To the contrary, a reduction in the present limit would require the expenditure of a great deal of money from which there will be little benefit. We believe that we must use our limited resources on controls which provide maximum benefit for each dollar expended.

6. Possible Alternative Actions

Under the circumstances, it is our recommendation that, rather than require a reduction of the exposure limit based upon the National Cancer Institute data, OSHA should at most consider promulgating a regulation which would require monitoring EDC exposures and medical surveillance and encourage training and good housekeeping programs.

Secondly, OSHA should undertake a critical evaluation of the National Cancer Institute study, as well as the various MCA studies when they become available. Certainly these data, together with data submitted in response to this inquiry, should put the Agency in a far better position to determine what reduction, if any, might be appropriate.

We appreciate the opportunity to make this submission. Should you have any questions or if we can help in any way, please contact the writer at 216/694-5268.

Very truly yours,

R. W. Hill
Senior Counsel

/njw

Enclosures

PERSONNEL SAMPLING LOG SHEET

June, 1978

MPLE O.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MASK WORN
1	6/7/78	Laboratory			8 hr.			9.5	No
2	6/7/78	Laboratory			8 hr.			25.5	No
3	6/7/78	Laboratory			8 hr.			10.85	No
4	6/8/78	Laboratory			8 hr.			19.66	No
5	6/8/78	Laboratory			9 hr.			8.76	No
6	6/8/78	Laboratory			8 hr.			8.21	No
7	6/14/78	Instrumcat			8 hr.			< 1	No
8	6/14/78	Welder			15 min.			< 1	No
9	6/14/78	EDC Operator			8 hr.	1		< 1	No
10	6/14/78	Millwright			8 hr.			4.2	No
11	6/14/78	Electrician			15 min.			< 1	No
12	6/21/78	EDC Operator			8 hr.	—		1.84	No
13	6/21/78	WWT Operator			8 hr.	—		2.56	No
14	6/21/78	OHC Operator			8 hr.	—		6.0	No
15	6/21/78	EDC Operator			8 hr.	—		2.7	No
16	6/21/78	VCM Operator			15 min. Est.	—		3.1	No
17	6/21/78	Head Operator			8 hr.	—		.65	No
18	6/21/78	WWT Operator			8 hr.	—		1.5	No

PERSONNEL SA...LING LOG SHEET

AMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MASK WORN
19	6/28/78	Head Operator			15 min.	—		.3	No
20	6/28/78	Shift Superintendent			8 hr.	—		.36	No
21	6/28/78	EDC Operator			8 hr.	—		1.0	No
22	6/28/78	Laboratory			8 hr.			.4	No
23	6/28/78	Loading Operator			8 hr.	—		.13	No

SL 080970

PERSONNEL SA[illegible]LING LOG SHEET

July, 1978

MPLE D.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MASK WORN
1	7/3/78	Laboratory			8 hr			.29	No
2	7/3/78	Laboratory			8 hr			.15	No
3	7/3/78	Laboratory			8 hr			.3	No
4	7/3/78	Laboratory			8 hr			.1	No
5	7/3/78	Laboratory			8 hr			.1	No
6	7/12/78	Head Operator			15 min.			.15	No
7	7/12/78	OHC Operator			8 hr			3.21	No
8	7/12/78	EDC Operator			8 hr.			1.39	No
9	7/12/78	OHC Operator			8 hr			.73	No
10	7/12/78	Shift Superintendent			8 hr.			.42	No
11	7/12/78	VCM Operator			8 hr.			.17	No
12	7/12/78	WWT Operator			8 hr.			.47	No
13	7/12/78	EDC Operator			8 hr.			2.78	No
14	7/12/78	VCM Operator			8 hr.			.18	No
15	7/12/78	Head Operator			8 hr.			.20	No
16	7/19/78	Loading Operator			8 hr.			.03	No
17	7/19/78	Loading Operator			8 hr.	Pump remained on for approx. 21 hr.		.03	No
18	7/19/78	Loading Operator			8 hr.			.02	No

SL 080971

PERSONNEL S. PLING LOG SHEET

SAMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MA WO
19	7/19/78	Loading Operator			8 hr.			.02	No
20	7/19/78	OHC Operator			8 hr.			1.06	No
21	7/19/78	WWT Operator			8 hr.			.37	No
22	7/19/78	Utility Helper			8 hr.			3.57	No
23	7/19/78	Millwright			8 hr.			2.19	No
24	7/19/78	Welder			8 hr.			.56	No
25	7/19/78	Inst. Engineer			8 hr.			.22	No
26	7/26/78	Loading Operator			8 hr.			.11	No
27	7/26/78	Loading Operator			8 hr.			.07	No
28	7/26/78	Utility Helper			8 hr.			.10	No
29	7/26/78	Loading Operator			8 hr.			.17	No
30	7/26/78	Laboratory			8 hr.			.34	No
31	7/26/78	Computer			8 hr.			.05	No
32	7/26/78	OHC Operator			8 hr.			102.6	No
33	7/26/78	Administrative			8 hr.			.02	No

SI 080972

PERSONNEL SA[illegible]LING LOG SHEET

August 1978

MPLE O.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MASI WORI
1	8/2/78	WWT Operator			8 hr.			.28	No
2	8/2/78	EDC Operator			8 hr.			1.72	No
	8/2/78	Materials Handler			8 hr.			.03	No
1	8/2/78	VCM Operator			8 hr.			.52	No
-	8/2/78	Loading Operator			8 hr.			.12	No
	8/9/78	Utility Helper			8 hr.			5.83	No
	8/9/78	Area Supervisor			8 hr.			.09	No
	8/9/78	VCM Operator			8 hr.			.37	No
2	8/9/78	Millwright			8 hr.			.14	No
	8/9/78	Pipefitter			8 hr.			.07	No
	8/9/78	welder			8 hr.			.84	No
2	8/9/78	Electrician			8 hr.			.07	No
3	8/16/78	EDC Operator			8 hr.			—	No
4	8/16/78	Laboratory			8 hr.			.12	No
	8/16/78	Loading Operator			8 hr.			.05	No
	8/16/78	welder			8 hr.			.12	No
	8/16/78	Maint. Foreman			8 hr.			.07	No
	8/16/78	Millwright			8 hr.			.62	No

SL 080973

PERSONNEL SAMPLING LOG SHEET

AMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MA WO
19	8/16/78	Mechanic			8 hr.	Notice - 8/28/78		0	No
20	8/23/78	Secretary			8 hr			.06	No
21	8/23/78	Head Operator			8 hr			.11	No
22	8/23/78	Engineer			8 hr.			.52	No
23	8/23/78	VCM Operator			8 hr.			.36	No
24	8/23/78	WWT Operator			8 hr.			.20	No
25	8/30/78	Head Operator			8 hr			.14	No
26	8/30/78	OHC Operator			8 hr.			1.23	No
27	8/30/78	EDC Operator			8 hr			1.82	No
28	8/30/78	WWT Operator			8 hr			.01	No
29	8/30/78	Area Supervisor			8 hr.			8.57	No
30	8/30/78	Laboratory			8 hr.			1.19	No

SL 080974

PERSONNEL SAMPLING LOG SHEET

September, 1978

AMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MAS WOR
1	9/6/78	Electrical Engr.			8 hr.			2.14	No
2	9/6/78	Instrument			8 hr.			.42	No
3	9/6/78	Electrical			8 hr.			.25	No
4	9/6/78	Pipefitter			8 hr.			.54	No
5	9/6/78	VCM Operator			8 hr.			1.51	No
6	9/13/78	welder			8 hr.			.07	No
7	9/13/78	Millwright			8 hr.			.17	No
8	9/13/78	OHC Operator			8 hr.			.82	No
9	9/13/78	Loading Operator			8 hr.			.23	No
10	9/13/78	Utility Helper			8 hr.			.66	No
11	9/13/78	Laboratory			8 hr			.44	No
12	9/20/78	Engineer			8 hr.			.16	No
13	9/20/78	Engineer			8 hr.			.12	No
14	9/20/78	Administrative			8 hr.			.11	No
15	9/20/78	Administrative			8 hr.			.24	No
	9/20/78	utility Operator			8 hr.			.51	No
	9/27/78	OHC Operator			8 hr.			.66	No
	9/27/78	WWT Operator			8 hr.			.083	No

SL 080975

PERSONNEL SAMPLING LOG SHEET

SAMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MAS WOR
19	9/27/78	VCM Operator			8 hr.			.96	No
20	9/27/78	VCM Operator			8 hr.			.49	No
21	9/27/78	Shift Superintendent			8 hr.			.29	No
						Average		.518	

SL 080976

PERSONNEL SAMPLING LOG SHEET

October 1978

SAMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	M... W...
1	10/4/78	Instrument			8 hr	DELIBERATE [illegible] OVEREXPOSURE [illegible]		119.05	YES
2	10/4/78	Pipefitter			8 hr			57.0	No
3	10/4/78	Electrician			8 hr			.449	No
4	10/4/78	Engineer			8 hr			.272	No
5	10/4/78	OHC Operator			8 hr			.254	No
6	10/11/78	Instrument			8 hr			1.1	No
7	10/11/78	Lab			8 hr			1.6	No
8	10/11/78	welder			8 hr			1.9	No
9	10/18/78	EDC Operator			8 hr	[illegible] OVEREXPOSURE NOTICE 10/23/78		1.38	No
10	10/18/78	Analyzer			8 hr			.06	No
11	10/18/78	VCM Operator			8 hr			.89	No
12	10/18/78	Engineer			8 hr			.97	No
13	10/25/78	EDC Operator			8 hr			.29	No
14	10/25/78	Head Operator			8 hr			.32	No
15	10/25/78	EDC Operator			8 hr			2.33	No
	10/25/78	EDC Operator			8 hr			.25	No
	10/25/78	OHC Operator			8 hr			1.67	No
	10/25/78	Loading Operator			8 hr			.57	No

SL 080677

PERSONNEL SAMPLING LOG SHEET

AMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	M W
19	10/25/78	Loading Operator			8 hr.			0.0	ND
20	10/25/78	Unit Operator			8 hr.			.56	ND

SL 080978

PERSONNEL S. PLING LOG SHEET

November 1978

AMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	M WO
1	11/1/78	Truck Loading			8 hr.	-		.21	No
2	11/1/78	VCM Operator			8 hr.	-		.23	No
3	11/1/78	EDC Operator			8 hr.	-		.05	No
4	11/1/78	Electrician			8 hr.			.05	No
5	11/1/78	Instrument			8 hr.			.21	No
6	11/1/78	Pipefitter			8 hr			.00	No
7	11/1/78	Maint. Foreman			8 hr.			.03	No
8	11/8/78	EDC Operator			8 hr.	-		2.28	No
9	11/8/78	Laboratory			8 hr.			.04	No
10	11/8/78	Head Operator			8 hr.	-		.05	No
11	11/22/78	Head Operator			8 hr	-		.11	No
12	11/23/78	OHC Operator			8 hr	-		.16	No
13	11/29/78	Laboratory			8 hr			.24	No
14	11/29/78	Pipefitter			8 hr.			2.2	Yes -
	11/29/78	Millwright			8 hr			.04	No -
	11/29/78	Foreman			8 hr.			.62	No
	11/29/78	Electrician			8 hr.			.16	No -
	11/29/78	Instrument			8 hr.			.39	No -

SL 080979

PERSONNEL SAMPLING LOG SHEET

MPLE O.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MASK WORN
19	11/29/78	OHc Operator			8 hr.	-		.61	No
o	11/29/78	Unit Operator			8 hr.	-		1.98	No

ST 080980

PERSONNEL SAMPLING LOG SHEET

DECEMBER - 1978 1 OF 2

SAMPLE NO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	MASK WORE
1	12-7-78	MILLWRIGHT			8 hr			2.61	NO
2	12-7-78	ENGINEER			8 hr			.53	NO
3	12-7-78	LABORATORY			8 hr			2.76	NO
4	12-7-78	WASTEWATER OPER.			8 hr			0.25	NO
5	12-7-78	EDC OPER			8 hr			4.6	NO
6	12-20-78	OXY AREA FOREMAN			8 hr			.38	NO
7	12-20-78	HEAD OPERATOR			8 hr			.31	NO
8	12-20-78	VCM AREA OPERATOR			8 hr			0.99	NO
9	12-20-78	TECH ROOM			8 hr			0.27	NO
10	12-20-78	ANALYSER TECH			8 hr			1.19	NO
11	12-20-78	INSTRUMENT			8 hr			0.05	NO
12	12-20-78	OXY AREA OPERATOR			8 hr			1.07	NO
13	12-20-78	UTILITY W/W OPER			8 hr			.33	NO
14	12-27-78	UTILITY W/W OPER			8 hr			.08	NO
	12-27-78	PIPE FITTER			8 hr			.57	NO
	12-27-78	DAY MAINT FOREMAN			8 hr			.30	NO
	12-27-78	EDC HEAD OPERATOR			8 hr			.23	NO
	12-27-78	VCM OPERATOR			8 hr	[illegible] Given - 1-4-79		1.00	NO

SL 080981

PERSONNEL SAMPLING LOG SHEET

DECEMBER 1978 20

MPLE IO.	DATE	JOB CLASSIFICATION	EMPLOYEES NAME	S.S. NUMBER	TIME	REMARKS	VCM PPM	EDC PPM	M WC
4	12-27-78	ELECTRICIAN 1st CL.			8/E			2.20	11

SL 080982

Interoffice Correspondence

To: K. W. Sanders
From: J. R. Whitfill
Date: January 10, 1979

D 118-C

Subject: PERSONNEL EXPOSURE TO EDC IN THE SOLVENTS PLANT

Listed below is a tabulation from February 1976 to October 1978 of personnel exposure to EDC in the Solvents Plant. These results are for an eight hour TWA in ppm by volume. We started using the statistical environmental monitoring program in February 1976, however, data is available back to 1973.

DATE		NO. OF SAMPLES	AVG.	LOW	HIGH
Feb., March, & April	1976	135	2.25	0.01	26.3
May, June, & July	1976	63	0.99	0.01	6.8
Aug., Sept. & Oct.	1976	363	2.77	0.01	31.9
Nov., Dec. & Jan.	1977	43	2.05	0.01	17.8
February	1977	44	4.31	0.40	27.1
March	1977	61	3.18	0.06	35.2
April	1977	47	4.37	0.09	61.0
May	1977	48	2.83	0.01	24.4
June	1977	46	2.98	0.01	22.0
July	1977	57	1.62	0.01	18.0
August	1977	41	1.89	0.01	13.3
September	1977	48	1.80	0.01	15.9
October	1977	54	5.28	0.01	85.6
November	1977	46	3.48	0.01	39.3
December	1977	40	3.72	0.01	23.3
January	1978	46	1.82	0.01	8.2
February	1978	51	1.67	0.01	5.5
March	1978	50	1.77	0.01	9.6
April	1978	48	2.01	0.01	16.8
May	1978	48	2.20	0.01	22.3
June	1978	54	3.79	0.05	36.8
July	1978	54	6.09	0.11	34.0
August	1978	65	3.74	0.10	40.7
September	1978	59	4.26	0.01	74.1

Jim Whitfill

Diamond Shamrock

SL 080983

Bio/Tox Research Laboratories, Inc.
553 NORTH BROADWAY
SPENCERVILLE, OHIO 45887
PHONE (419) 647-4196

MUTAGENIC STUDIES

July to December 1975

PREPARED BY:

Bio/Tox Research Laboratories, Inc.
553 North Broadway
Spencerville, Ohio 45887

CONDUCTED FOR:

Electro Chemicals Division
Diamond Shamrock Chemical Company
P. O. Box 191
Painesville, Ohio 44077

Mr. Jack Borror

SUPERVISED BY:

Mamdouh H. Abou-Youssef, Ph.D., Project Manager

Tana L. Joy, M. T. (ASCP) Lab Supervisor

SL 080984

Introduction

There is considerable evidence that, with few exceptions, carcinogens are mutagens.[1,2,3,4] This supports the desirability of using this type of rapid and economical test system as a pre-screening technique to pinpoint potentially dangerous chemicals among the thousands of chemicals to which humans are exposed. A great deal of evidence that carcinogens are mutagens has been obtained using very sensitive and simple bacterial systems for detecting chemical mutagens. Such systems are generally inexpensive, allow the screening of large number os chemicals in a relatively short period of time, and most proximal carcinogens exhibit genetic activity when tested.[1,2,5,6] Since many of the chemical carcinogens require metabolic activation *in vivo*, it becomes necessary to employ either a mammalian host or an appropriate *in vitro* enzyme system to carry out the essential activation of these compounds.

The Host-Mediated Assay technique was developed by Gabridge and Legator [7] to bridge the gap between *in vitro* microbial studies and definitive tests in mammals. In this assay, the mammal, during treatment with a potential chemical mutagen, is injected with an indcator microorganism in which mutation frequencies can be measured. After a sufficient time period, the microorganisms are withdrawn from the animal and the induction of mutants is determined.[8] The host-mediated assay is particularly suited to identify those agents requiring activation by more than a single tissue or organ.

References Cited

1. Ames, B. N., The Detection of Chemical Mutagens with Enteric Bacteria. In Chemical Mutagens: Principles and Methods For Their Detection, A. Hollaender (Ed.), Plenum Press, New York and London (1971).

2. Ames, B. N., A Bacterial System For Detecting Mutagens and Carcinogens. In Mutagenic Effects of Environmental Contaminants. M. E. Sutton & M. I. Harris (Ed.) Academic Press, New York (1972).

3. Ames, B. N., Lee, F. D. & Durston, W. E. An Improved Bacterial Test System for the Detection and Classification of Mutagens and Carcinogens. Proc. Nat. Acad. Sci., U.S.A. 70:782-786 (1973).

4. McCann, J. and Ames, B. N. A Simple Method for Detecting Environmental Carcinogens as Mutagens. Annals of New York Acad. Sci. in press (1975).

5. McCann, J., Spingarn, N. E., Kobari, J., and Ames, B. N. Detection of Carcinogens as Mutagens: Bacterial Tester Strains with R Factor Plasmids, Proc. Natl. Acad. Sci., U.S.A. 72 (1975) 979-983.

6. Zimmerman, F. K. Induction of Mutatic Gene Conversion by Mutagens, Mutation Res. 11:327 (1971).

7. Gabridge, M. G. and Legator, M.S. A Host-Medicated Microbial Assay for the Detection of Mutagenic Compounds. Proc. Soc. Exptl. Biol. Med. 130:831 (1969).

8. Legator, M. S. and Malling, H. V. The Host-Mediated Assay, A Practical Procedure for Evaluating/Potential Mutagenic Agents in Mammals. In Chemical Mutagens, A. Hollaender (Ed.), Plenum Press, New York and London (1971).

I. In Vitro Mutagenicity

Test Methodology

1. Test Organisms: Four (4) histidine-dependent strains of S. typhimurium (TA-1530, TA-1535, TA-98 and TA-100) and two (2) tryptophan-dependent strains of E. Coli (B/r-WP_2 and B/r-WP_2-hcr) were used.

2. Mutation Test Media for S. typhimurium: Minimal agar media was prepared by dissolving in distilled water (800 ml), successively, $MgSO_4.7H_2O$ (0.2 gm), citric acid H_2O (5.0 gm), K_2HPO_4 (10.0 gm), $NaNH_4PO_4$ (3.5 gm), and agar (15.0 gm). The media was sterilized by autoclaving. Before pouring plates, 200 ml of sterile 20% glucose was added to the media.

3. Mutation Test Media for E. Coli: Minimal agar media was prepared by dissolving in distilled water (800 ml), successively, $(NH_4)_2\ SO_4$ (1.0 gm), KH_2PO_4 (20.0 gm), $MgSO_4$ (0.1 gm), trisodium citrate (0.05 gm), and agar (15.0 gm). The pH was adjusted to 7 with KOH and the media was sterilized by autoclaving. Before pouring plates, 200 ml of sterile 2% glucose was added to the media.

4. Top Agar: Top agar was prepared by dissolving 0.6 gm agar and 0.6 gm NaCl in 100 ml distilled water. Top agar was sterilized by autoclaving. The top agar was used for both E. Coli and S. typhimurium mutation test; 5 ug/ml tryptophan and 50 uM histidine-HCl/50 uM biotin were added to top agar, respectively. The trace of tryptophan and histidine

in the top agar allows the bacteria on the plates to undergo several divisions; this gro[illegible] is necessary in many cases for mutagenesis to occur.

Procedure

1. To tubes containing 2-5 ml of top agar, kept at 45°C in a water bath, 0.1 ml of tester strain culture was added. The tubes were then mixed and poured onto the center of petri plates of minimal agar media.

2. After the top agar had hardened, compounds were added to the plates. One (1) to five (5) ug of the compound was added near the edge of the plate with a spatula.

3. Controls of spontaneous mutation and positive controls using nitrofuran for E. Coli and B-propiolactone for S. typhimurium were included for each tester strain on separate plates.

4. Plates were incubated at 37°C for 48 hours. Results are reported as (+) for positive, (-) for negative or (±) for questionable.

Explanation of Table

Table I summarizes in vitro results of the compounds tested for mutagenic activity. Salmonella typhimurium TA-1530, TA-1535, TA-98 and TA-100, and E. Coli ATCC #23231 and ATCC #23233 were used as indicators. Results are reported as (-), (+) or (±).

TABLE I

In Vitro Results of 1,2 Dichloroethane Tested for Mutagenic Activity.

	In Vitro					
	E. Coli		S. Typhimurium			
Compound	ATCC-23231	ATCC-23233	TA-1530	TA-1535	TA-98	TA-100
1,2 - Dichloroethane	(-)	(-)	(-)	(-)	(-)	(-)
Positive Control						
B-propiolactone	(-)	(-)	(+)	(+)	(+)	(+)
C=63 (Nitrofuran)	(-)	(-)	(NT)	(NT)	(NT)	(NT)

(-) sign indicates that no mutagenic activity was detected

(NT) Not tested

SL 080990

II. Sub-Acute Host-Mediated Assay

Materials

1. Animals: Swiss male albino mice, weighing 18-23 grams were used.

2. Test Organism: Histidine-dependent S. typhimurium TA-100 was used. The tester strain was inoculated into tryptone broth and incubated for two hours at 37°C before used.

3. Media:

   a. Minimal agar media was prepared as mentioned earlier (in vitro mutagenicity test).

   b. Tryptone agar media was prepared by dissolving 10 gms of tryptone and 15 gms agar in 1000 ml distilled water. The media was sterilized by autoclaving.

4. Compounds: Three (3) levels of test chemical compounds were dissolved or suspended in 10% ethanol saline.

Procedure

1. Mice were divided into four (4) groups of ten (10) mice each.

2. Groups of mice were treated as follows:

Treatment	Number of Animals
High level	10
Intermediate Level	10
Low Level	10
Negative Control	10

All animals were dosed orally by intubation for five days.

3. The tester strain of S. typhimurium (TA-100) was diluted 1:10 with tryptone broth and incubated for 2 hours at 37°C. before use. Two milliliter of the resulting suspension was injected intraperitoneally into each mouse.

4. All mice were killed four (4) hours later and 2 ml of sterile saline was injected intraperitoneally. As much fluid as possible was removed aseptically from the peritoneal cavity and put in sterile tube.

5. Ten-fold serial dilutions of each peritoneal exudate yielding a concentration series from 10^{-0} through 10^{-7} were made in sterile saline.

6. For enumeration of total bacterial counts, 10^{-6} and 10^{-7} dilutions were plated on tryptone agar; three (3) plates per sample, 0.1 ml per plate.

7. For total mutant counts, 10^{-0} and 10^{-1} dilutions were plated on minimal agar; three (3) plates per sample, 0.2 ml per plate.

8. Plates were incubated at 37°C.; tryptone agar plates for 18 hours; minimal agar plates for 40 hours.

9. Bacterial scoring was calculated as follows:

$$\text{CFU/ml of sample/plate} = \frac{\text{No. colonies/plate}}{\text{No. plates}} \times \frac{5 \text{ (mutant)}}{10 \text{ (total count)}}$$

$$\text{CFU/ml} \times \text{dilution factor} = \text{CFU/ml in undiluted sample}$$

$$\text{Mutation frequency (MF)} = \frac{\text{Total mutants}}{\text{Total bacterial count}}$$

Explanation of Tables

Table II summarizes the host-mediated assay results for mutagenic activity. The compound was administered orally to mice for five (5) days.

Conclusion*

Test was considered negative since the mutation frequency of test compound was not significantly greater than that of negative control.

*The EDC study, and the conclusions drawn therefrom, was part of a study conducted by Diamond Shamrock encompassing numerous other compounds.

TABLE II

Host-mediated Assay Results following Sub-acute Administration (Intubation) of 1,2 Dichloroethane in Mice.

Compound	Concentration mg/kg/day x 5	Mean MF*	MFt/MFc**
1,2-Dichloroethane	450	5×10^{-7}	1.2
	45	3×10^{-7}	0.8
	4.5	2×10^{-7}	0.5

* Mean MF = Mean Mutation Frequency = $\frac{\text{Mean total mutant cells}^{a}}{\text{Mean total bacterial cells}^{b}}$

[a] Mean total mutant cells = $\frac{\text{total mutant cells per 10 mice}}{10}$

[b] Mean total bacterial count = $\frac{\text{total bacterial count per 10 mice}}{10}$

** MFt/MFc = Ratio between mean mutation frequency of test chemical (MFt) and mean mutation frequency of negative control (MFc).[c]

$$(MFt/MFc)^{c} = \frac{\text{Mutation Frequency of experimental sample}}{\text{Mutation Frequency of control sample}}$$

MFt/MFc = 1.00 for control sample

III. Dominant Lethal Assay

Objective

The objective of the dominant lethal study was to evaluate the mutagenic potential of 1,2 dichloroethane when given orally to sexually mature male rats.

Materials

1. Test Chemicals

The test chemical was received from Electro Chemicals Division, Diamond Shamrock Chemical Company on July 8, 1975.

2. Positive Control

Cytoxan^{R}, brand of cyclophosphamide, was obtained from Mead Johnson Company, Evansville, Indiana.

3. Animals

Sexually mature male and female rats (11-14 weeks old), Sprague-Dawley derived rats were obtained from Spartan Research Animals, Haslett, Michigan and from Flow Labs, Dublin, Virginia.

Methods

1. Housing

All rats were housed in wire bottom cages suspended over litter. Males were housed individually or with one (1) female during breeding. Females were individually housed during quarantine and after breeding. Commercial rat feed in pellet form (Purina^{R} Rat Chow^{R} - Ralston Purina Company,

St. Louis, Missouri) and water were available ad libitum at all times.

2. Dosing

Dosing solutions or suspensions were prepared in peanut oil. The positive control solution was prepared by dissolving cyclophosphamide in sterile distilled water to make 20 mg/ml. Peanut oil was used as negative control solution.

3. Dosage Groups

a. Acute Treatment

The male rats were divided into selected dosage groups for an acute (single oral dose) study. Positive control rats were dosed intraperitoneally. Rats assigned to test compounds were dosed orally. The experimental design was as follows:

Compound	Group	No. of Males	Treatment*
1,2-Dichloroethane	1	10	17.5 mg/rat
	2	10	35.0 mg/rat
	3	10	70.0 mg/rat
	4	10	140.0 mg/rat
Positive Control	1	10	40.0 mg/rat
Negative Control	1	40	2.0 ml/rat

* Doses were administered at a constant volume of 2 ml/rat.

b. Subacute Treatment

The male rats were divided into selected dosage groups for the subacute study. Animals were dosed orally by

intubation for five (5) consecutive days at a total dose equal to the dose employed on the previously cited acute study. The experimental design was as follows:

Compound	Group	No. of Males	Treatment/Day For 5 Days*
1,2-Dichloroethane	1	10	3.5 mg/rat
	2	10	7.0 mg/rat
	3	10	14.0 mg/rat
	4	10	28.0 mg/rat
Positive Control	1	10	40.0 mg/rat
Negative Control	1	40	2.0 ml/rat

* Doses were administered at a constand volume of 2.0 ml/rat.

4. Mating

Males in the acute studies were placed in breeding cages immediately after dosing, while males in the subacute studies were placed in breeding cages after the fifth dose.

Each male was paired with one, 11-14 week old, virgin female rat for seven (7) days. On the seventh day each male was removed and placed with a new female. This procedure was repeated weekly for eight (8) weeks.

5. Maintenance and Observations

Females were received five (5) days prior to mating, checked for illness, and isolated individually until they were placed with males.

After seven (7) days with males, the females were again housed individually for 12 days. They were then sacrificed on day 19 and necropsied. Uteri were removed, implantation sites examined, resorptions and formed fetuses were counted, and fetal deaths were noted. Percent fertility, number of implantations, and number of resorptions were recorded by week.

Males were observed daily for compound effects. Food and water intake of both sexes were monitored daily for changes.

6. Statistical Methods

Fertility, implantation sites per female, and number of deaths per gravid female were compared by use of the Student's-t test. All groups were compared to the positive control and to their respective negative control groups ($P < .01$).

Results

1. Mortality

Table III summarizes the results of the acute and subacute percent survival of male rats treated with 1,2-dichloroethane. Deaths were recorded according to dose of compound per rat.

The only death during the studies occurred in week three in a high dose subacute male.

Table III

Male Treatment And Percent Survival

1,2-DICHLOROETHANE

Acute Study

Single Dosage (mg/rat)	Weeks 1	2	3	4	5	6	7	8
17.5	100	100	100	100	100	100	100	100
35	100	100	100	100	100	100	100	100
70	100	100	100	100	100	100	100	100
140	100	100	100	100	100	100	100	10
Negative Control	100	100	100	100	100	100	100	100
Positive Control	100	100	100	100	100	100	100	100

Subacute Study

5 Daily Dosages (mg/rat)	Weeks 1	2	3	4	5	6	7	8
3.5	100	100	100	100	100	100	100	100
7	100	100	100	100	100	100	100	100
14	100	100	100	100	100	100	100	100
28	100	100	90	90	90	90	90	90

SL 080999

2. Fertility

Results of percent fertility for test chemicals are shown in Tables IV and V. These tables show no differences in the percent fertility in the acute or subacute studies when compared with the saline negative control group results.

3. Implant Sites

Results of average implants per gravid female are shown in Tables VI through VII. The acute study (Table VI) shows that the test chemical has no effect on the implant sites. However, the subacute study (Table VII) indicates that there were instances of weekly implantation sites per female being lower than the negative control.

4. Resorption and Fetal Death

Tables VIII and IX show results of average resorptions per gravid female for acute and subacute studies on 1,2-dichloroethane. There were no significant differences between test and negative control groups in the acute study (Table VIII). There was one instance of weekly resorptions being higher than negative control at 28 mg/rat in the subacute study (Table IX). However, there was no dose relationship in number of resorptions across groups on a total basis.

Table IV

Percent Fertility

1,2-DICHLOROETHANE

Acute Study

Single Dosage (mg/rat)	Weeks 1	2	3	4	5	6	7	8	Cumulative Mean	ation
17.5	90.0	100.0	90.0	100.0	100.0	100.0	100.0	100.0	97.50	(4.63)
35	90.0	100.0	100.0	90.0	90.0	100.0	100.0	100.0	96.30	(5.18)
70	80.0	70.0	100.0	100.0	90.0	100.0	90.0	100.0	91.30	(11.26)
140	80.0	100.0	100.0	100.0	100.0	100.0	80.0	80.0	92.50	(10.35)
Negative[a] Control	85.0	97.5	95.0	97.5	97.5	90.0	97.5	97.5	94.69	(4.71)
Positive[b] Control	80.0	90.0	100.0	100.0	90.0	90.0	40.0	20.0	76.25	(29.73)

[a] = Peanut Oil
[b] = Cyclophosphamide

SL 081001

Table v

Percent Fertility

1,2-DICHLOROETHANE

Subacute Study

5 Daily Dosages (mg/rat)	Weeks 1	2	3	4	5	6	7	8	Cumulative Mean	Standard Deviation
3.5	90.0	90.0	100.0	100.0	90.0	90.0	100.0	70.0	91.25	(9.91)
7	70.0	80.0	100.0	100.0	100.0	90.0	90.0	60.0	86.25	(15.06)
14	90.0	100.0	100.0	100.0	100.0	100.0	80.0	60.0	91.25	(14.58)
28	100.0	90.0[a]	100.0	100.0	100.0	100.0	88.9	77.8	94.58	(8.30)
Negative[b] Control	85.0	97.5	95.0	97.5	97.5	90.0	97.5	97.5	94.69	(4.71)
Positive[c] Control	80.0	90.0	100.0	100.0	90.0	90.0	40.0	20.0	76.25	(29.73)

[a] = Male died on last day of breeding period: non pregnant female may not have been bred.
[b] = Peanut Oil
[c] = Cyclophosphamide

SL 081002

Table VI

Average Implants Per Gravid Female

1,2-DICHLOROETHANE

Acute Study

Week	Dosage (mg/rat) 17.5	35	70	140	Negative[a] Control	Positive[b] Control
1	14.1	14.4	13.3	13.0	14.2	15.0
2	14.1	14.6	13.6	13.1	12.0	11.7
3	14.3	14.6	14.5	14.4	13.8	12.1
1-3 Ave.	14.2	14.5	13.8	13.5	13.3	12.9
4	13.5	14.0	13.1	14.8	14.6	14.0
5	14.3	14.3	14.0	13.7	14.6	13.9
6	14.1	14.7	13.8	12.5	14.0	13.2
7	14.7	12.8	14.3	14.1	14.0	12.5
8	12.6	13.7	12.9	14.0	14.0	9.5
4-8 Ave.	13.8	13.9	13.6	13.8	14.2	12.6
Mean	14.0	14.1	13.7	13.7	13.9	12.7
(S.D.)[c]	(0.65)	(0.64)	(0.58)	(0.78)	(0.83)	(1.71)

[a] = Peanut Oil
[b] = Cyclophosphamide
[c] = S. D. = Standard Deviation

SL 081003

Table VII

Average Implants Per Gravid Female

1,2-DICHLOROETHANE

Subacute Study

	5 Daily Dosages (mg/rat)					
Week	3.5	7	14	28	Negative Control[a]	Positive Control[b]
1	14.1	14.2	16.0	13.3	14.2	15.0
2	12.1	11.0	13.8	13.7	12.0	11.7
3	13.8	13.6	14.0	13.4	13.8	12.1
1-3 Ave.	13.3	12.9	14.6	13.5	13.3	12.9
4	11.2-N[c]	12.6-N	12.9-N	11.8-N	14.6	14.0
5	13.0-N	14.1	13.8	13.4	14.6	13.9
6	13.3	12.3	12.9	13.2	14.0	13.2
7	13.6	12.3-N	11.8-N	14.9	14.0	12.5
8	12.9	11.8	13.3	11.7	14.0	9.5
4-8 Ave.	12.8-N	12.6-N	12.9-N	13.0	14.2	12.6
Mean	13.0	12.7	13.6	13.2	13.9	12.7
(S.D.)[d]	(0.96)	(1.15)	(1.22)	(1.03)	(0.83)	(1.71)

[a] = Peanut Oil
[b] = Cyclophosphamide
[c] = Significantly decreased ($P < 0.01$)
[d] = Standard Deviation

SL 081004

Table VIII

Average Resorptions Per Gravid Female

1,2-DICHLOROETHANE

Acute Study

Week	Dosage (mg/rat) 17.5	35	70	140	Negative[a] Control	Positive[b] Control
1	1.10	0.56	1.25	0.38	0.94	4.75
2	0.80	1.40	0.43	1.20	0.69	2.67
3	0.67	0.50	1.20	0.50	0.71	3.10
1-3 Ave.	0.86	0.82	0.96	0.69	0.78	3.51
4	0.80	0.67	0.50	0.90	0.49	2.50
5	0.70	0.67	1.33	1.30	0.72	1.00
6	0.60	0.40	0.70	0.80	1.64	0.67
7	0.80	0.80	0.78	0.38	0.77	0.50
8	1.10	0.60	1.20	0.63	0.97	1.00
4-8 Ave.	0.80	0.63	0.90	0.80	0.92	1.13
Mean	0.82	0.70	0.92	0.76	0.87	2.02
(S.D.)[c]	(0.189)	(0.308)	(0.363)	(0.356)	(0.347)	(1.488)

[a] = Peanut Oil
[b] = Cyclophosphamide
[c] = Significantly decreased ($P < 0.01$)

Table IX

Average Resorptions Per Gravid Female

1,2-DICHLOROETHANE

Subacute Study

Week	5 Daily Dosages (mg/rat) 3.5	7	14	28	Negative Control [a]	Positive Control [b]
1	1.11	1.14	1.11	0.70	0.94	4.75
2	1.56	1.50	1.60	1.33	0.69	2.67
3	1.00	1.20	0.70	1.67+N [c]	0.71	3.10
1-3 Ave.	1.22	1.28	1.14	1.23	0.78	3.51
4	0.90	1.20	1.20	1.44	0.49	2.50
5	1.56	0.50	0.60	1.11	0.72	1.00
6	0.78	1.56	1.20	1.33	1.64	0.67
7	0.80	0.89	0.50	0.75	0.77	0.50
8	0.14	1.00	0.88	0.51	0.97	1.00
4-8 Ave.	0.84	1.03	0.88	1.03	0.92	1.13
Mean	0.98	1.12	0.97	1.11	0.87	2.02
(S.D.) [d]	(0.457)	(0.338)	(0.370)	(0.398)	(0.347)	(1.488)

(P =<.01)

[a] = Peanut Oil
[b] = Cyclophosphamide
[c] = Significantly elevated (P = < .01)
[d] = Standard Deviation

SL 081006

Conclusions*

Statistical analysis of the data comparing numbers of implants and dead per litter in control versus test groups indicate that 1,2-dichloroethane may be suspect. We suggest that 1,2-dichloroethane be tested again.

*The EDC study, and the conclusions drawn therefrom, was part of a study conducted by Diamond Shamrock encompassing numerous other compounds.

SL 081007

13

MANUFACTURING CHEMISTS ASSOCIATION

1825 CONNECTICUT AVENUE, N.W., WASHINGTON, D.C. 20009

ALBERT C. CLARK
VICE PRESIDENT
TECHNICAL DIRECTOR

TELEPHONE: (202) 328-4240
TELEX: 89617 (MCA WSH)

December 18, 1978

Docket Officer
U. S. Department of Labor
Occupational Safety and Health
Administration
Third Street and Constitution Ave., N. W.
Washington, D. C. 20210

Subject: Request for Information--Occupational Exposure to 1,2-Dichloroethane, Docket No. 11-079

Dear Sir:

Please be advised that the following studies on 1,2-Dichloroethane (EDC) are being administered by the Manufacturing Chemists Association (MCA).

Inhalation--being conducted by Professor Maltoni of Montedison and Dr. Spreafico of "Mario Negri". Exposures have been completed and the pathology is in progress. (See my letters dated December 22, 1978 and June 6, 1978, sent to the Honorable Eula Bingham, Assistant Secretary of Labor.)

Metabolism--being conducted by Dr. Spreafico of "Mario Negri".

Teratology--being conducted at The Toxicology Research Laboratory, The Dow Chemical Company.

Reproduction--being conducted at The Toxicology Research Laboratory, The Dow Chemical Company.

As is MCA's policy, all final reports will be sent to the appropriate government agencies as they become available.

Sincerely,

SL 081008