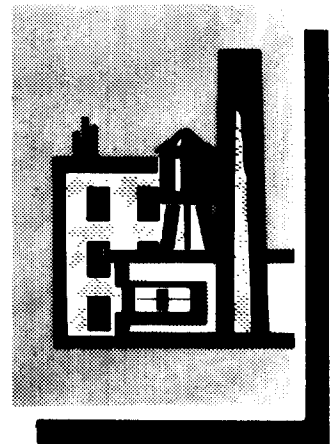
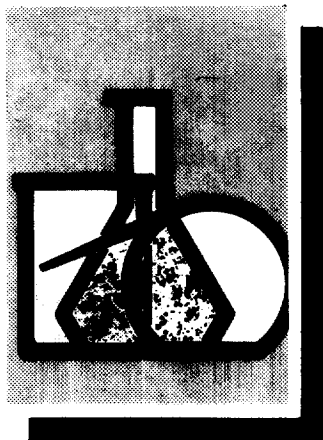
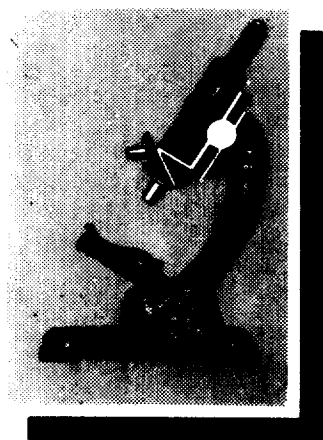


NIOSH

SPECIAL OCCUPATIONAL HAZARD REVIEW with CONTROL RECOMMENDATIONS



Trichloroethylene



**U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Center for Disease Control
National Institute for Occupational Safety and Health**

SPECIAL OCCUPATIONAL HAZARD REVIEW OF
TRICHLOROETHYLENE

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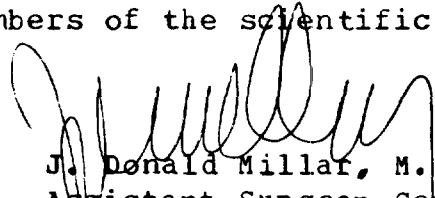
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Foreword

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of workers exposed to an ever-increasing number of potential hazards in their workplace. Pursuant to the fulfillment of this need, the National Institute for Occupational Safety and Health (NIOSH) has developed a strategy of disseminating information about adverse effects of widely used chemical or physical agents intended to assist employers in providing protection for employees from exposure to substances considered to possess carcinogenic, mutagenic, or teratogenic potential. This strategy includes the development of Special Occupational Hazard Reviews which serve to support and complement the other major standards development or hazards documentation activities of the Institute. The purpose of Special Occupational Hazard Reviews is to analyze and document, from a health standpoint, the problems associated with a given industrial chemical, process, or physical agent, and to recommend the implementation of engineering controls and work practices to ameliorate these problems. While Special Occupational Hazard Reviews are not intended to supplant the more comprehensive NIOSH Criteria Documents, nor the brief NIOSH Current Intelligence Bulletins, they are nevertheless prepared in such a way as to assist in the formulation of regulations. Special Occupational Hazard Reviews are disseminated to the occupational health community at large, e.g., trade associations, industries, unions, and members of the scientific community.



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ABSTRACT

Trichloroethylene (TCE) has been an important industrial chemical for the past 40 years, primarily because of its utility as a highly effective solvent. While the great majority of TCE has been used for vapor degreasing of metal parts, it also has had many other applications, including use as a cold solvent, a solvent in food processing, in drycleaning, as an anesthetic, and as a heat-transfer medium. U.S. production in 1977 is estimated to be in excess of 115-million kilograms (253-million pounds). NIOSH estimates that over 100,000 workers are exposed full time to TCE, with up to 3-1/2-million more workers subjected to continuous low levels or to brief exposures of various levels.

This hazard review provides a brief description of the production, uses, toxicity, and metabolism of TCE and a more detailed assessment of TCE's potential as a workplace carcinogen. In addition, the results of a recent survey of industrial vapor degreasing operations, the primary source of occupational exposures to TCE, are presented along with data from other surveys or reviews to document the extent and nature of occupational exposures to TCE and existing control methods.

TCE's acute toxicity is well known and is related mainly to central nervous system depression, cardiac arrhythmias, and dermal effects. In contrast, chronic effects are not as well documented under usual occupational exposure conditions. There is evidence, however, for latent effects, including those of the liver, kidneys, and nervous system. Toxic effects have been reported in animal studies as well as in workers chronically exposed to TCE levels around 100 ppm, the current OSHA permissible limit.

The earliest concern for TCE's carcinogenic potential was based upon its structural and metabolic similarities to vinyl chloride. Subsequently, an animal bioassay conducted by the National Cancer Institute documented carcinogenicity in mice but not in rats after exposure to TCE by gavage. Several positive mutagenic tests and malignant transformation of cultured cells have also been reported. Overall, however, the results do not indicate a strong response.

There is strong presumptive evidence that a highly reactive metabolite, trichloroethylene epoxide, is produced during the metabolism of TCE and is likely responsible for the carcinogenic and mutagenic activity of TCE. This metabolite has been synthesized and confirmation of its formation during *in vitro* metabolism has been obtained and it has been demonstrated capable

of covalent binding with cellular macromolecules, including DNA. Spectral evidence for the formation of trichloroethylene epoxide in vivo has also been obtained; however, the extent and nature of biochemical interactions in the intact animal, including the formation, inactivation, and possible activity of intermediate metabolites, has not been resolved as yet. Nevertheless, the evidence for such potential reactivity, associated with carcinogenicity, is strong.

No evidence is known which associates TCE with an increased risk of cancer in humans. However, epidemiology studies to test for such an association have only recently been initiated. The first reports provide preliminary results of studies underway in Finland and Sweden. No association of TCE with cancer has been found. The investigators cautioned against ruling out carcinogenicity, however, as the sensitivity of the studies is low and the period of observation short.

Based upon this special review of all these data, NIOSH concludes that TCE has a carcinogenic potential in the workplace; however, it is not considered to be a potent carcinogen. The results of NIOSH surveys indicated that substantial exposures are occurring in vapor degreasing operations that could be largely abated by proper maintenance, modification, and operation of existing equipment, and by the education of employees and supervisors as to the potential hazards of TCE.

Based on the toxic effects at the current OSHA limit and the carcinogenic potential of TCE, several control recommendations are made to provide for an improved degree of worker protection. Among these are: reduction in permissible exposure limit, use of existing engineering technology, and improved work practices.

Many current degreasing operations, including open top tanks, are maintaining a time-weighted average (TWA) of considerably less than 50 ppm. NIOSH considers that a level of 25 ppm, as a TWA, can be uniformly achieved by use of existing engineering control technology. However, this should not serve as a final goal; rather, industry should exert a concerted effort to develop methodology which would enable an even further reduction in worker exposure. It is considered unwise at this time for industry to substitute other organochlorine solvents for TCE, as these also exhibit health and environmental hazards. Hazard reviews or updates of existing NIOSH criteria documents for two possible substitutes, tetrachloroethylene and methyl chloroform, are planned.

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I. INTRODUCTION

Trichloroethylene (TCE), CAS No. 79-01-6, a volatile liquid at room temperature, has been an important industrial chemical for the past 40 years. Its main use has been as an industrial solvent for liquid or vapor degreasing of metal parts. It has also been used for a variety of other applications including: (1) an extractant for substances of natural origin (e.g., waxes and greases from cotton or wool) and in food processing (e.g., manufacture of spices and caffeine-free coffee), (2) a drycleaning solvent, (3) cold degreasing solvent, (4) a component in rust prevention formulations, (5) an analgesic or anesthetic, and (6) a heat-transfer medium (Hardie, 1971).

While such varied applications of TCE have promoted its wide usage, it has also been well recognized that it produces both acute and chronic health effects. Some of the toxic properties of TCE have been known since 1911, when Lehmann discovered its narcotic effect. Several comprehensive toxicology reviews have been published, including those of von Oettingen (1937, 1955), Browning (1953), NIOSH (1973), Aviado et al. (1975), Fuller (1976), International Agency for Research on Cancer (1976), and Waters et al. (1977). The major concerns have been with CNS depression, cardiac arrhythmias, dermal irritation, and liver-kidney toxicity. In 1972 the Occupational Safety and Health Administration (OSHA) adopted, as a workplace standard, the standard of the American National Standards Institute (ANSI, 1967) for workplace exposure to TCE of 100 ppm (525 mg/m³) as an 8-hour time-weighted average (TWA) concentration, 200 ppm as an acceptable ceiling limit, and 300 ppm as a peak exposure limit during not more than 5 minutes in any 2-hour period.

In 1973, the National Institute for Occupational Safety and Health (NIOSH) issued Criteria for a Recommended Standard for Occupational Exposure to Trichloroethylene. This document provided a comprehensive review of the uses, exposures, and known biological effects of TCE. Based upon that review, NIOSH recommended that occupational exposures to TCE be controlled so that no worker shall be exposed to a peak concentration in excess of 150 parts of TCE per million parts of air (ppm) as measured over a maximum sampling time of 10 minutes or to a concentration in excess of 100 ppm determined as a time-weighted average exposure for an 8-hour workday. Various control measures, medical surveillance, and methods of chemical analysis were recommended. The OSHA standard and the NIOSH recommended standard and control measures were based upon TCE's known toxic properties at that time, but did not include an assessment of its carcinogenic potential.

Occupational health standards for TCE vary greatly throughout the world with respect to the maximum allowable exposure levels. While a few countries other than the United States have set 100 ppm as the environmental limit, many others have set much lower limits, as shown in Table 1. The lowest limits are those of several Eastern European countries at less than 2 ppm (10 mg/m³).

Table 1. Occupational standards for trichloroethylene

Country	mg/m ³	ppm
Australia	535	100
Spain	535	100
United Kingdom	535	100
United States of America	535	100
Austria	267	50
Egypt	267	50
Federal Republic of Germany	267	50
Finland	267*	50
Japan	267*	50
Switzerland	267	50
Yugoslavia	267*	50
German Democratic Republic	250	47
Czechoslovakia CSSR	250	47
Sweden	160	30
Hungary	53	10
Rumania	53	10
Bulgaria	10**	2
Poland	10**	2
Soviet Union USSR	10	2

* Recent changes from 535 to 267 mg/m³
 ** Recent changes from 50 to 10 mg/m³

Following the confirmation in 1974 that vinyl chloride was carcinogenic in animals and man, the similarity in chemical structure and metabolism of TCE to vinyl chloride (Van Duuren, 1975; Corbett, 1975), led to speculation that TCE might also have a potential for carcinogenesis. On March 21, 1975, the National Cancer Institute (NCI) released a preliminary report of an animal bioassay indicating carcinogenicity of TCE in mice (Saffiotti, 1975). Based upon those results, NIOSH issued (June 6, 1975) a brief announcement alerting the occupational community to the potential carcinogenicity of TCE. OSHA followed this action on October 20, 1975, by proposing a modification of its occupational exposure standard. While OSHA expressed concern as to the

possible carcinogenicity of TCE, it nevertheless believed that treating TCE as a human carcinogen solely on the preliminary NCI data and the NIOSH alert was inappropriate. Based on concern for other toxic effects, OSHA proposed to modify the occupational standard so as to retain the 8-hour TWA limit of 100 ppm based on a 40-hour work week, but to reduce the 200 ppm ceiling limit to 150 ppm, as averaged over a 15-minute period, and to eliminate the concept of an allowable peak concentration limit above the ceiling limit (OSHA, 1975). Although the final results of the NCI tests were published in February 1976 (NCI, 1976), OSHA has not as yet taken further action.

A more recent review of the use of anesthetic gases and vapors, including TCE, has been conducted by NIOSH (NIOSH, 1977b). In view of well-established toxic effects found among occupationally exposed medical and dental personnel, including maternal and fetal effects and possible carcinogenicity, NIOSH recommended that exposure to halogenated anesthetic gases, including TCE, be controlled so as not to exceed 2 ppm, sampled over a period not to exceed 1 hour. A similar review made in 1974 by the Hospital Engineering Cooperative Groups of Denmark (see NIOSH, 1977b), resulted in their recommendation of 3 ppm as the highest permissible average concentration of TCE in the breathing zone of anesthesiology personnel.

In response to the NCI announcement, and the controversial nature of the results, a number of studies were initiated or planned to further explore the carcinogenic potential of TCE. Among these was an attempt by NIOSH to establish a retrospective epidemiologic study to assess the carcinogenic risk to workers under the usual occupational conditions. At the time of this writing, an appropriate worker population exposed to TCE has not been identified for study. Other research, however, was initiated in several laboratories, including animal and in vitro studies. Some of these studies are of a long-term nature and will not be completed for another 1-2 years. A NIOSH survey of degreasing operations which use TCE and other industrial solvents indicates little change in operations or intensity of exposures since the NCI announcement. NIOSH believes that sufficient experimental evidence has now accrued to demonstrate a possible carcinogenic potential of TCE in the occupational environment. It is the intent of this document to present the results of the NIOSH survey, to review the toxicity of TCE, to conduct a carcinogenic hazard appraisal, and to recommend appropriate controls based upon the assessment of hazard from occupational exposure to TCE.

II. CHEMICAL AND PHYSICAL PROPERTIES

At room temperature, TCE is a clear, colorless, noncorrosive, heavy liquid with a sweet odor characterized as ethereal or chloroform-like, and a reported odor threshold ranging from 21 to 400 ppm. Its important physical properties are listed in Table 2.

Table 2. Physical properties of trichloroethylene

Molecular Formula:	C_2HCl_3 , $ClHC = CCl_2$
Molecular Weight:	131.4
Percentage Composition:	C=18.24%; H=0.77%; Cl=80.95%
Physical State:	Colorless liquid
Specific Gravity:	1.46 (20°/4°C)
Melting Point:	-73°C
Boiling Point:	87.1°C (760 mm Hg.)
Vapor Pressure:	57.8 mm Hg, 20°C 146.8 mm Hg, 40°C
Vapor Density (1 atm. B.P.):	4.5 g/liter (air = 1.2 g/l)
Autoignition Temperature:	410°C
Decomposition Temperature:	700°C
Flash Point:	None by standard methods
Odor Threshold:	21.4 ppm
Solubility in Water:	0.11 g/10 μ g H_2 , 20°C
Soluble in:	Ethanol, chloroform, ethyl ether
Conversions:	1 mg/liter = 186.1 ppm 1 ppm = 5.38 mg/m ³ at 25°C

Volatility/Flammability - Trichloroethylene is volatile, but neither flammable nor explosive at room temperature. It is only moderately flammable at higher temperatures, with an ignition temperature of 410°C (Patty, 1962). However, mixtures of TCE and oxygen will ignite at temperatures above 25.5°C when the TCE concentration is between 10.3 and 64.5% (Jones and Scott, 1942). While such mixtures are not normally encountered in degreasing operations, they could constitute a hazard during the use of TCE as an anesthetic agent.

Solubility - Trichloroethylene is practically insoluble in water and is not readily hydrolyzed by water. It is readily miscible in a variety of organic solvents including ether, chloroform, acetone, benzene, and various alcohols.

Stability/Degradability - Trichloroethylene decomposes under a number of environmental conditions and may degrade to more hazardous compounds. Among these are phosgene, carbon monoxide, dichloroacetylene, TCE ozonides, hydrochloric acid, and TCE epoxide. In the presence of oxygen and light, especially ultraviolet radiation, TCE undergoes autooxidation, decomposing to such acidic products as hydrogen chloride. High temperatures, especially above 125°C, further promote the degradation process, with the production of phosgene and hydrogen chloride. These same compounds are readily produced when TCE in either liquid or vapor form comes into contact with hot metals, such as magnesium and aluminum, at 300-600°C. Such conditions may be found in the vicinity of arc welding and degreasing operations (Smith, 1966). Of the metals, aluminum is the most reactive and can initiate violent reactions with unstabilized TCE. Storage of TCE for prolonged periods should be in steel or plastic cans or dark glass bottles (Noweir et al., 1973). Stowell (1943) cautioned that dangerous amounts of phosgene might be generated within an operating room during use of TCE as an anesthetic simultaneously with the use of a high-frequency cautery. This hazard is particularly likely to be present during surgical procedures within the oral cavity.

In the presence of strong alkali, e.g., sodium hydroxide, dichloroacetylene (C_2Cl_2), an explosive, flammable, and highly toxic agent may be formed. In 1944 Humphrey and McClelland reported two human fatalities and several nonfatal cases of severe toxicity resulting from trichloroethylene anesthesia. In all cases, the toxicity was attributed to dichloroacetylene, formed as the TCE passed through a soda-lime canister used as a CO_2 absorbent in closed circuit anesthesia systems. During the first MESA (Manned Environmental Systems Assessment) test run, the mission was aborted because of the formation of dichloroacetylene (DCA) from TCE used to clean the equipment in the chamber. In this case, the DCA was produced as the TCE passed through the sodium superoxide used to remove CO_2 , adsorb acid gases and regenerate O_2 . Although the test subjects became extremely sick, there were no fatalities. Dichloroacetylene can decompose further to phosgene and carbon monoxide, also highly toxic chemicals (Lehmann, 1911).

Chloroacetyl chloride and chloral (Cl_3CCHO) may be formed in the presence of anhydrous aluminum chloride. Impurities, including oxidants, can promote the sudden decomposition of TCE. In the presence of moisture, dichloroacetic acid and hydrochloric acid are formed. Such acidic products are highly corrosive and reactive with many metals. Ozone will react with TCE to yield an ozonide which is explosive and which decomposes to hydrogen chloride, phosgene, carbon monoxide, and chlorine peroxide (Hardie, 1971). Glycolic acid ($CH_2OHCOOH$) is produced upon

reaction of TCE under pressure at 150°C, with alkaline hydroxides. Monochloroacetic acid results when TCE is reacted with 90% sulfuric acid.

It should thus be obvious that the hazard from TCE must be judged not only on the basis of its own toxicity but also on those of the products that may be produced by reaction with other chemicals present during the processes in which TCE is used.

Stabilizers/Inhibitors - TCE readily undergoes free radical-type autooxidation which can be prevented by the addition of various stabilizers or inhibitors. The most common stabilizer in medical grade TCE is a mixture of thymol and ammonium carbonate, usually in concentrations of 0.01 and 0.02%, respectively (Aviado, 1972). Industrial grades of TCE may contain a variety of stabilizers. Among the stabilizers used in the past for industrial grade TCE have been substances having antioxidant properties, such as simple amines; those capable of fixing hydrochloric acid, such as epoxy compounds; and other compounds used mainly as metal deactivators, such as ethanolamine and aniline (Hardie, 1971). More recently, stabilizers have tended to be synergistic mixtures of antioxidant organic compounds. An example is the use of diisopropylamine plus an alkyl-p-hydroxyanisole (Huff, 1971). Other stabilizers which are effective inhibitors of oxidation include acetone, acetylenic compounds, aniline, borate esters, n-butane, o-cresol, ethyl acetate, hydrazine derivatives, isobutyl alcohol, lactones, o-nitrophenol, pyrazoles, stearates, and SO₂. Additional chemicals that have been patented for use as TCE stabilizing agents include epichlorohydrin (U.S. Patent 2,818,446, Dec. 31, 1957) and 1,4-dioxane (U.S. Patent 3,763,048, Oct. 2, 1973). Normally, stabilizers are effective at concentrations of less than 1 percent (by weight).

The ability of these agents to stabilize TCE is lost at temperatures above 130°C, especially in the presence of air, moisture, light, and common construction metals, which will corrode in such circumstances. At temperatures above 700°C, TCE vapor will decompose, even with oxidation inhibitors present in the liquid TCE, to yield a mixture of various organochlorine compounds, including methyl chloride, dichloroethylene, tetrachloroethylene, carbon tetrachloride, and chloroform. Vigorous heating in the presence of air will result in complete oxidation of TCE vapor to carbon dioxide and hydrogen chloride.

III. MANUFACTURE, PRODUCTION, USES, AND EXPOSURE

A. MANUFACTURE

Trichloroethylene was first synthesized by Fisher in 1864 by the reduction of hexachloroethane with hydrogen. In large-scale commercial production, TCE is usually manufactured from either of two starting materials: acetylene or ethylene. Chlorination of acetylene yields 1,1,2,2-tetrachloroethane ($\text{CHCl}_2\text{CHCl}_2$), which is dehydrochlorinated by alkaline hydrolysis (i.e., reaction with calcium hydroxide), or by pyrolysis (i.e., reaction with mixed metallic chlorides at 300-500°C), to yield TCE (Hardie, 1971). The yield of TCE from acetylene is approximately 94% of the theoretical, or 4.8 pounds of TCE per 1.0 pound of acetylene consumed in the reaction (Blackford, 1975).

Chlorination of ethylene yields 1,2-dichloroethane, which is then oxychlorinated (reaction with chlorine and oxygen) to yield tetrachloroethane. Dehydrochlorination to TCE is then accomplished as described above for acetylene (Hardie, 1971). It is estimated that 85% of the total TCE produced in 1963-67 was manufactured using acetylene as a starting material. This decreased to only 8% in 1973-74 (Blackford, 1975). Now most TCE (85%) is manufactured using ethylene as a starting material. This trend is due to the cost differential between acetylene and the less expensive ethylene as raw materials (NIOSH, 1973, 1976d).

B. PRODUCTION VOLUME

TCE was first produced commercially in 1908 in Austria and England and in 1910 in Germany but not until 1925 in the United States. Its first uses in this country were in extraction processes and the formulation of boot polish, printing ink drier, and similar products. In the 1930's new applications for TCE and advances made in metal degreasing and drycleaning resulted in an increasing demand for the chemical. A steady increase in U.S. production of TCE continued through the 1960's, a peak annual production of 277 million kilograms (610 million pounds) being reached in 1970 by the five TCE manufacturers. During the next 6 years, as shown in Table 3, production of TCE declined at an average annual rate of about 9%, and is estimated to amount to about 117 million kilograms (257 million pounds) in 1977.

The U.S. capacity for producing TCE has also experienced a general decline, from about 352 million kilograms (775 million pounds) per year in 1968 to about 277 million kilograms (610 million pounds) per year in 1975 (Blackford, 1975). The declines

in production and capacity have resulted somewhat from a national economic recession but perhaps more from air pollution control legislation, such as Los Angeles' Rule 66 in 1966 and the 1970 Federal Clean Air Act. Such legislation, which might impose restrictions on the use of TCE, has caused uncertainty about this chemical's future. Already other chlorinated solvents have been substituted for TCE in certain processes, e.g., replacement by tetrachloroethylene in the drycleaning trade. Further, the recent announcement of positive carcinogenic test results for TCE by the National Cancer Institute (NCI, 1976) has prompted TCE's replacement in some food-processing operations, e.g., decaffeination of coffee. It is estimated that total domestic consumption of TCE will decline at an average annual rate of 2% through 1979 and that total U.S. production will decline at an average annual rate of 1.2% during that same period, with TCE exports accounting for most of the excess production (Blackford, 1975).

Table 3. U.S. production and consumption of trichloroethylene

Year	Production x10 ⁶ kg	Consumption* x10 ⁶ kg	Exports x10 ⁶ kg	Imports x10 ⁶ kg
1958	122.9	NA	NA	15.7
1962	161.5	NA	NA	29.5
1970	276.7	276.1	14.8	13.9
1971	233.5	214.1	23.6	4.2
1972	193.5	202.0	19.1	27.5
1973	204.9	208.6	17.8	21.5
1974	176.4	157.4	19.6	0.6
1975	132.8	121.2	15.4	3.8
1976	137.6	128.5	16.1	7.0
1977	116.6**	100.2	26.0	9.7***

* Represents production plus imports minus exports

** Estimated from 1st 5 months production data

*** Estimated from 1st 9 months of import/export data

Data from U.S. International Trade Commission (1971-1977), Blackford (1975), U.S. Exports, FT 410, U.S. Dept. of Commerce, Bureau of the Census (1975-77) and U.S. Imports for Consumption and General Imports, FT 246, U.S. Dept. of Commerce, Bureau of the Census (1975-77).

NA = Not Available

C. USES

Approximately 92% of the TCE produced by U.S. manufacturers is actually consumed in the U.S., the remaining 8% being exported. Of the amount consumed in the United States, approximately 95% is used as a vapor-degreasing solvent, 3% as an extraction solvent, and 2% for miscellaneous uses (Faith et al., 1975).

In the past TCE was by far the most popular solvent for vapor degreasing. However, its use in this industrial process has experienced a decline in recent years because of the restrictive air pollution control legislation and the depressed state of the U.S. economy. Consumption trends indicate that TCE's use in metal cleaning operations should decline at an average annual rate of 3% through 1979 (Blackford, 1975).

As an extraction solvent, TCE has been used in the processing of alkaloids, fish meal, leather, meat meal, oil-containing seeds, sheepskins, and soya and coffee beans. It should be noted that the largest U.S. producer of decaffeinated coffee abandoned the use of TCE soon after the NCI announcement (Fuller, 1976).

TCE is used in numerous other applications, including use as a drycleaning solvent, as a component of fungicides, adhesives, and lubricants, as a low-temperature heat transfer agent, as a chain terminator in the production of polyvinyl chloride, and as an analgesic and anesthetic (Fuller, 1976). As an anesthetic, TCE has been used mainly in short operative procedures, such as in obstetrics, dentistry, burn dressing, and cystoscopy, and in veterinary practice. As an analgesic it has been used mainly for treatment of trigeminal neuralgia, for women in labor, and for dental extraction. A 1975 NIOSH survey of 1,254 hospitals found that 5% were utilizing TCE in certain anesthetic procedures (NIOSH, 1977b). However, the only manufacturer of anesthetic-grade TCE has discontinued its production (Coakley, 1976) and no other company seems to have entered this market. Consumption trends indicate that TCE use in miscellaneous applications (including extraction) may grow at an average annual rate of 6% through 1979 (Blackford, 1975).

D. EXTENT OF OCCUPATIONAL EXPOSURE

From the National Occupational Hazard Survey ("NOHS"), NIOSH (1976e), estimates that approximately 3.5 million persons are occupationally exposed on a part- or full-time basis to TCE and, further, that approximately 92% of these people are exposed in operations where control measures specific for TCE are ineffective. NIOSH further estimates that approximately 100,000 persons are exposed on a full-time basis and that approximately 67% of these are working in operations where control measures are

absent or inadequate. It should be noted that these estimates are based on information collected during the period 1972-74 and are thought to be more accurate than the estimate of 200,000 people exposed occupationally as presented in the 1973 NIOSH Criteria Document on TCE.

The NOHS also revealed that the greatest levels of exposure to TCE are in metal cleaning processes, especially in vapor degreasing. U.S. consumption rates show, however, that this trend is shifting (refer to Section III-3 on Use). Exact TCE-exposure estimates are difficult to obtain because of the fluctuation in use trends and because the TCE-component of many cleaning agents and industrial solvents may be masked by a trade name.

While the great majority of degreaser operators may be men, there are many women employed in operations in close proximity to degreasers. The actual exposure levels may, in general, be lower than that directly around the degreaser. However, the numbers of workers thus exposed may be greater. The NIOSH Health Hazard Evaluations and a survey of degreaser operations, to be discussed later, document such exposures of women. Thus, while past concern has been expressed primarily for effects of TCE on adults, consideration for fetal effects should also be included in any hazard assessment. Dow estimated that there were over 25,000-vapor degreasers in use in the United States in 1974, most of which were classified as open-top units (Skory et al., 1974). That figure is likely a realistic estimate of the current number of degreasers in use, with TCE one of the major solvents in use.