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PROFILES ON OCCUPATIONAL HAZARDS

FOR CRITERIA DOCUMENT PRIORITIES

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16. Abstracts

The definition, nature, production, uses, toxicity, environmental data, exposure estimates, standards, and properties of classes of chemicals, physical hazards, industrial processes, and chemicals are summarized in a series of data sheets. The main topics covered are: aldehydes; epoxy compounds; organic acids; arenes; alkenes; brominated aliphatics; alcohols; glycols; silicon-acetates; heavy metal greases and soaps; alkali earth metal petroleum sulfonates; aluminum; organophosphate compounds; zinc and zinc compounds; phthalates; barium; glycol ethers; rubber processing chemicals; plasticizers; lubricant, oil, and grease additives; aliphatic and aromatic amines; visible light; vibration; impact noise; nonionizing radiation; synthetic rubber manufacture; paint manufacturing; tire manufacturing; leather tanning; dyeing and refinishing textiles; wood preserving; pulp and paper mills; smelting and refining; manufacturing of non-metallic pigments; caisson and compressed air work; plastics manufacturing; entering confined spaces; naphthalene; diphenyl; terphenyl; ammonium nitrate; organochlorine compounds; sodium azide; pyrolysis fuel; tetrahydrofuran.

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CLASSES OF CHEMICAL HAZARDS

ALDEHYDES

I. Description

Aldehydes are a very widely used group of organic compounds with the general chemical formula $R\text{-}C\overset{O}{\underset{H}{<}}$. This class of compounds includes industrially important unsaturated and saturated aliphatic, heterocyclic, and aromatic aldehydes and dialdehydes (excluding formaldehyde). The following list includes available production figures:

	million lbs.	yr.
acetaldehyde	1500	1976
n-butyraldehyde	1077	1973
furfural (2-furaldehyde)	149.6	1974
propionaldehyde	140	1973
acrolein	61.73	1974
benzaldehyde	3.4	1968
cinnamaldehyde	1.75	1973
p-anisaldehyde	1.06	1972
hydroxycitronellal	0.68	1973
∝-pentylcinnamaldehyde	0.659	1973
citronellal	0.640	1973
glutaraldehyde		
piperonal		
glyoxal		
ketene		
succinaldehyde (butanedial)		
salicylaldehyde		
crotonaldehyde		
geranial		
vanillin		
adipaldehyde (Hexanedial)		
methacrolein		

II. Production

Aldehydes are an important and widely used group of compounds with many industrial and commercial uses. Two industrially important processes used in the preparation of aldehydes are the catalytic dehydroformylation of alkenes (Oxo process). The catalytic dehydrogenation of alcohols is usually accomplished at 200-300°C in the presence of copper or copper chromite. In the hydroformylation reaction, a mixture of carbon monoxide, hydrogen, and an alkene is heated under pressure in the presence of a catalyst such as dicobalt octacarbonyl. In the U.S. several companies currently produce aldehydes.

III. Uses

There are many different uses for aldehydes and some individual aldehydes have more than one important use. They are industrially important as chemical intermediates in the manufacture of alcohols, acids, plastics, synthetic resins, rubber accelerators, solvents, dyes, plasticizers, and other compounds. Aldehydes, especially the aromatic and higher aliphatic members of the group, are also associated with the manufacture of perfumes (odorants) and flavor chemicals.

IV. Toxicity Information

Major toxic effects of this class of chemicals are to the skin, eyes, and respiratory tract. There are reports of some aldehydes affecting the central nervous system, liver, kidney, and blood elements.

Acetaldehyde

Mouse - oral, LD50 1232 mg/kg
Rat - oral, LD50 1930 mg/kg
Rat - inhalation, LCLo 4000 ppm/4 hr
Human - inhalation, TCLo 134 ppm is the lowest published toxic concentration at which irritant effects were observed.

Butyraldehyde

Rat - oral, LD50 2490 mg/kg
Human - inhalation, TCLo 580 mg/cu m is the lowest published toxic concentration at which irritant effects were observed.

Furfural

Mouse - oral, LD50 425 mg/kg
Rat - oral, LD50 127 mg/kg
Rat - inhalation, LCLo 153 ppm/4 hr
Rabbit - oral, LD50 928 mg/kg
Dog - oral, LD50 2300 mg/kg
Human - inhalation, TDLo 600 ug/cum is the lowest published toxic dose at which toxic effects on the eye were observed.

Acrolein

Mouse - inhalation LCLo 24 mg/cum/6 hr
Rat - oral, LD50 46 mg/kg
Rat - inhalation, LCLo 8 ppm/4 hr
Rabbit - oral, LD50 7 mg/kg
Rabbit - skin, LD50 562 mg/kg
Rabbit - inhalation, LCLo 24 mg/cum/6 hr
Cat - inhalation, LCLo 1570 mg/cum/8 hr
Human - inhalation, LCLo 153 ppm/10 min
Human - inhalation, TCLo 1 ppm is the lowest published toxic concentration at which irritant effects were observed.

Benzaldehyde

Rat - oral, LD50 1300 mg/kg

p-Anisaldehyde

Rat - oral, LD50 1510 mg/kg

Cinnamaldehyde

Mouse - ip, LD50 200 mg/kg
Rat - oral, LD50 2220 mg/kg

α-Pentylcinnamaldehyde

Rat - oral, LD50 3730 mg/kg

Glutaraldehyde

Rat - oral, LD50 2380 mg/kg
Rat - inhalation, LCLo 5000 ppm/4 hr
Rabbit - skin, LD50 2560 mg/kg

Piperonaldehyde

Rat - oral, LD50 2700 mg/kg

Aldehydes may exert toxic effects as a result of ingestion, inhalation, and absorption through the skin. In industrial exposures effects due to inhalation and skin contact are most likely.

Acute/subchronic effects

Aldehydes tend to cause primary irritation of the skin, eyes, and respiratory tract. The lower aldehydes, which are very soluble in water, exhibit the most pronounced irritant action and mainly affect the eyes and tissues of the upper respiratory tract. The higher aldehydes are much less soluble in water and tend to penetrate deeper into the respiratory system where they may affect the lungs. The primary irritant effects of aldehydes are most pronounced in the lower members of the series and in those which are unsaturated in the aliphatic chain.

Inhalation of aldehyde vapors appears to present the most serious health hazard in an occupational environment. The volatility of a particular aldehyde will help determine whether its irritant effects will be stronger or milder. Those compounds with high vapor pressures may rapidly form hazardous atmospheric concentrations of vapor. Excessive atmospheric concentrations of aldehyde vapors may cause irritation to the eyes (powerful lachrymatory agent), nose, throat, tightness of the chest, shortness of breath, nausea, vomiting, headaches, stupor, bronchitis, and pulmonary edema. The hazardous effects on the bronchi and lungs may be severe. It has been reported that recovery from acute exposure to acrolein is possible, although permanent lung damage may be detected by radiological examination and functional damage to the bronchi and lungs may persist. The vesicant action of aldehydes has been shown in animal experiments. Respiratory function may be fully inhibited as a result of damage to the mucous membranes of the respiratory tract.

Repeated skin contact with liquid aldehydes may cause dermatitis and sensitization. Such irritant dermatitis may become eczematous. Direct sensitization to vapor seems to be relatively rare. Severe skin burns may result from contact with the more irritating aldehydes such as acrolein.

Effects due to ingestion of aldehydes include nausea, diarrhea, narcosis, respiratory failure and damage to the kidneys, liver, heart, and CNS. These compounds may exert a narcotic action on central nervous system when introduced orally or parenterally. However, aldehydes are often such potent irritants, that in an industrial setting, enough of the compound will not voluntarily be inhaled for these effects to be observed. In this respect, aldehydes possess excellent warning properties in the industrial environment.

Long-term effects

Prolonged and repeated exposure to aldehydes may cause dermatitis, conjunctivitis, irritation of mucous membranes, fatigue, headache, loss of sense of taste, and nervous disorders (tremors, numbness of tongue). However, it is reported that these effects appear to be relatively uncommon, and that they usually disappear after cessation of exposure. Symptoms such as loss of weight, anemia, delirium, hallucinations of sight and hearing, loss of intelligence, and psychic disturbances have been reported as a result of chronic intoxication with acetaldehyde. Sustained rise in blood pressure and decrease of white cells, red cells, and hemoglobin have also been seen in chronic exposure to acetaldehyde. Delayed respiratory damage and toxicity similar to phosgene have been observed as effects produced with ketene, acrolein, crotonaldehyde, and others.

One source reports carcinogenicity of acetaldehyde after subcutaneous administration to rats. No other reports of carcinogenicity, mutagenicity, or teratogenicity as a result of exposure to aldehydes were identified.

V. Standards

The following are Threshold Limit Values for Chemical Substances in Workroom Air adopted by the ACGIH for 1976:

Acetaldehyde	100 ppm	(180 mg/cu m)
Furfural - skin	5 ppm	(20 mg/cu m)
Acrolein	0.1 ppm	(0.25 mg/cu m)
Glutaraldehyde	0.3 ppm	(1.2 mg/cu m)
(activated + unactivated)	-	ceiling values
Ketene	0.5 ppm	(0.9 mg/cu m)
Succinaldehyde	0.3 ppm	(1.2 mg/cu m)
	-	ceiling values
Crotonaldehyde	2 ppm	(6 mg/cu m)

VI. Environmental Data

Precautions should be taken to prevent injury resulting from contact with aldehydes in liquid and vapor form. Proper ventilation and respiratory equipment as well as protective clothing and equipment should be used where necessary.

Because of the flammability, volatility, and reactivity of some aldehydes (especially the lower members), fire and explosion hazards may be severe. Vapors of aldehydes may rapidly form flammable and explosive mixtures in air and therefore proper precautions should be taken. Some aldehydes may undergo rapid and violent condensation reactions in the presence of

alkaline or acid contamination. Proper storage precautions should thus be taken.

The odor and irritant action of an aldehyde is often sufficient warning of its presence and workers should be aware of this.

Identification of Informational Gaps

Industrial experience with aldehydes does not seem to indicate any long-term serious health effects. Although aldehydes enjoy very widespread use, there are few comprehensive health studies of their effects. Long-term studies in animals to dertermine if any serious chronic hazards exist are necessary. Epidemiological studies of persons exposed to aldehydes (especially long-term) at known atmospheric concentrations should be undertaken. In addition, since use of aldehydes is so widespread and varied it might be useful to catalogue more accurately the types of processes they are involved in and the number and identity of workers potentially exposed.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Cinnamaldehyde		45,000
Glutaraldehyde		45,000
Hydroxycitronellal		45,000
Piperonal		30,000
Airolein	less than	5,000
Anisaldehyde	less than	5,000
Benzaldehyde	less than	5,000
Furfural	less than	5,000
Glyoxal	less than	5,000
-Pentylcinnamaldehyde	less than	5,000
Acetaldehyde	less than	1,000
Ketene	less than	1,000
Salicylaldehyde	less than	1,000
Succinaldehyde	less than	1,000

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ORGANIC OXIDES OR EPOXY COMPOUNDS

I. Description

All epoxy compounds incorporate in their chemical structure. Those epoxy compounds having major industrial importance are:

1) Ethylene oxide
2) Propylene oxide
3) Butylene oxide
4) Styrene oxide

The epoxides can present dangerous fire and explosion hazards.

Those organic oxides identified as being industrially important are:

1) Diphenyl oxide
2) Monomethoxymethyl diphenyl oxide
3) Dichloromethyl diphenyl oxide
4) Monochloromethyl diphenyl oxide
5) Bis(tributyltin) oxide

The diphenyl oxides are moderately flammable and can be fire hazards at high environmental temperatures. Due to the low vapor pressure of diphenyl oxide it does not present an inhalation hazard at room temperature.

II. Production and Use

1. Ethylene oxide - In 1975, 4,425 million pounds were produced by 12 companies. By 1980, the capacity is expected to reach 6,757 million pounds/year. The major uses of ethylene oxide are as an intermediate in the manufacture of ethylene glycol, polyethylene glycol, glycol ethers, ethanolamines, and surface-active agents.

2. Propylene oxide - In 1975, 1,523 million pounds were produced by five companies. By 1980, the capacity is expected to reach 3,315 million pounds/year. The major uses of propylene oxide are as an intermediate in the manufacture of propylene glycol, polyurethane polyols, surfactants, solvents, resins, and crude oil demulsifiers.

3. Butylene oxide - There is 1 producer of butylene oxide, Dow Chemical; no production figures are available. It is made from n-butene, of which 7 million pounds were consumed in 1974 for butylene oxide. The demand for butylene oxide over the near term is expected to decline; by 1980 only 1 million pounds of n-butene will be consumed for butylene oxide production.

4. Styrene oxide - There is 1 producer, Union Carbide; no production information is available. In 1972, 209 million pounds of styrene were consumed for production of styrene oxide and styrenated oils. Styrene oxide is used as a reactive diluent in epoxy resin production, and in the manufacture

of varnishes.

5. Diphenyl oxide - There are two producers, Dow Chemical and Monsanto; no production information is available. It is used as a heat transfer media, in perfumery, and as a chemical intermediate in the production of surface active agents and high temperature lubricants.

6. Methyl diphenyl oxides - Stauffer Chemical is the only producer of these compounds. The monomethoxy compound is a monomer used in electrical wire coating in the aerospace industry. Less than 100 thousand pounds have been made over the last six years, and its use is expected to decrease in the future. The mono and dichloro compounds are also only made to a limited degree. The monochloro compound is used in the production of monomethoxymethyl diphenyl oxide. Less than 50 thousand pounds was made in 1976. The dichloro compound is used in the manufacture of thermoplastic resins. Less than 5 thousand pounds was made in 1976.

7. Bis(tributyltin) oxide - There is one producer, American Can Company; production figures are not available. It is used as a fungicide, as a catalyst, in flame resistant polyester, as a wood preservative, as a curing agent, for water repellant coatings, and as a corrosion inhibitor.

III. Toxicity Information

A. Toxic Values:

LD50 - oral - rat (mg/kg)

Ethylene oxide	330
Propylene oxide	930
Styrene oxide	4290
Diphenyl oxide	3370
Bis(tributyltin) oxide	148-194

LD50 - skin - rabbit (mg/kg)

Propylene oxide	1500
Butylene oxide	2100
Styrene oxide	1060

LC50 - 4HR - mouse (ppm)

Ethylene oxide	836
Propylene oxide	1740

LCLo - rats (ppm)

Butylene oxide	4000
Styrene oxide	500 (4HR)

B. Toxic Effects

The epoxy compounds effect the surface tissues, mucous membranes, central nervous system, lungs and liver. The low molecular weight monoepoxides are weakly anesthetic and are strong irritants. Monoepoxides can cause a nonspecific depression of the CNS. Aliphatic epoxies, diepoxy compounds, and monoepoxy compounds are strong irritants of mucous membranes and surface tissues. Inhalation can cause acute pulmonary edema and chemical pneumonia. Skin irritation can be produced to varying degrees up to necrosis. Dermatitis has been reported to be a major problem; sensitization can affect up to 2% of the exposed population. The incidence of dermatitis runs between 10-60%. Epoxides have been found to have radiomimetic effects. One investigator observed atypical cells in the peripheral blood of some workers using epoxy compounds. Occasional reversal of the percent of granulocytes and nongranulocytes and depression of the total white count were observed. Using rats, mice, and dogs, epoxides administered parenterally caused a decrease in the number of nucleated cells in the bone marrow, in the total number of circulating white cells, and in the predominant white cell type of the peripheral blood. A number of bisepoxides have been found to be tumor inhibitory. Vapors of the epoxy compounds can cause irritation and necrosis of the eyes.

Some investigators have produced tumors in animals after repeated exposure to epoxy compounds, either cutaneously or subcutaneously. Some have suggested that epoxides may be one of the carcinogenic agents in the polluted air of cities. No tumors have been reported to have arisen in man from exposure to epoxy compounds. A dose of 30 mg/m^3 of ethylene oxide by inhalation to an unspecified mammal has been reported to cause mutagenic effects. A dose of 96 mg/kg of styrene oxide by inhalation caused neoplastic changes to the mouse.

Diphenyl oxide has a low acute oral toxicity. The undiluted material can be irritating to the skin after prolonged or repeated exposure, and can cause erythema and exfoliations. The diluted form is not irritant to the skin. The mono and dichloromethyl diphenyl oxides are semi-corrosive materials, and are handled as such in industry.

IV. Standards

U.S. Federal Standard - ppm

Ethylene oxide	50(90 mg/m^3)
Propylene oxide	100(240 mg/m^3)
Diphenyl oxide	1(7 mg/m^3)

ACGIH TLV - ppm (1976)

Ethylene oxide	50(90 mg/m^3)
Propylene oxide	100(240 mg/m^3)

Recommendation by Patty

Butylene oxide	400 ppm

Foreign Standards - TLV

Bulgaria	
Ethylene oxide	1 mg/m^3
Finland	
Ethylene oxide	50 ppm
Propylene oxide	100 ppm
Japan	
Ethylene oxide	50 ppm
Poland	
Ethylene oxide	1 mg/m^3
Rumania	
Ethylene oxide	10 mg/m^3
Propylene oxide	100 mg/m^3
USSR	
Ethylene oxide	1 mg/m^3
Yugoslavia	
Ethylene oxide	18 mg/m^3
Propylene oxide	240 mg/m^3

V. Environmental Data

No information on environmental data has been found.

VI. Needs for Research

The long term effects of exposure to epoxy compounds or organic oxides are not known. The carcinogenic, mutagenic, and teratogenic potential of these compounds needs to be explored further. Information on the concentrations of these compounds found in the workplace is needed.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Organic oxides, unclassified	600,000
Ethylene oxide	125,000
Propylene oxide	90,000
Butylene oxide	200,000
Styrene oxide	90,000

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ORGANIC ACIDS

I. Description of Chemicals

Organic acids include carboxylic, sulfonic, sulfinic, dicarboxylic, and disulfonic acids. The organic acids considered here are carboxylic and dicarboxylic acids. Based on production and consumption data, the most economically important acids are:

> acetic, adipic, maleic, acrylic, stearic, benzoic, propionic, fumaric, isophthalic and phthalic acids.

The organic acid derivative anhydrides, have important uses in the chemical industry. Examples of these are phthalic and maleic anhydrides, that have been used in the manufacturing of plasticizers, unsaturated polyester resins, alkyd resins, nylons, lubricants, and intermediates in synthesis.

II. Production

A. Manufacturing

Organic acids are produced using simple processes.

B. Production

Organic Acid	Millions of Pounds		Year
	Production	Consumption	
Acetic	2,050.0	2,040.0	1971
Adipic	1,478.0	1,475.0	1974
Maleic	283.2	283.2	1974
Acrylic	233.0	210.0	1974
Stearic	94.4	---	1974
Benzoic	81.0	81.0	1974
Propionic	60.4	---	1973
Fumaric	53.5	26.0	1973
Formic	46.9	46.9	1974
Phthalic	---	---	
Isophthalic	110.0 (1976)	45.0 (1972)	

The production of adipic and fumaric acids is anticipated to grow with annual growth rates of 7 and 2 percent, respectively.

III. Uses

The organic acids are mainly used in the manufacturing of synthetic fibers and textiles, alkyd resins, plasticizers, nylon and organic synthetic processes. They can also be used in preparing organic acid esters which have applications as solvents in food processing, cosmetics, and chemical intermediates.

IV. Toxicity Information

A. Target Organs

Organic acids cause skin, eye and mucuous membrane irritation. Some organic acids also affect the lungs and digestive system.

B. LD50 Valves

Organic Acid		g/kg
Acetic	rat, oral	3.30
Adipic	mouse, oral	1.90
Maleic	rat, oral	0.71
	rabbit, skin	1.56
Acrylic	rat, oral	0.34
Stearic	rat, intravenous	0.02
Benzoic	rat, oral	3.04
	mouse, oral	2.37
	mouse, intraperitoneal	1.46
Propionic	rat, oral	1.51
	mouse, oral	1.37
	rabbit, oral	1.90
Fumaric	mouse, intraperitoneal	0.02
Formic	rat, oral	1.20
	mouse, oral	1.10
	mouse, intravenous	0.14
Isophthalic	mouse, intraperitoneal	4.20

C. Acute/Subchronic Effects

The toxicity of organic acids varies from no possible injury in the case of stearic acid to severe damage to skin, eye or mucosal surface in cases of formic and acetic acids. Both benzoic and acetic acids, besides skin irritation, can cause digestive derangement, i.e., nausea and vomiting.

D. Long-Term Effects

The long-term effects also vary from none in the case of stearic acid to causing dermatitis, bronchitis, ulcer, erosion of exposed teeth and conjunctivitis in acetic acid.

It has been reported that no cumulative effects resulted to the skin and mucuous membranes from prolonged exposure to maleic and propionic acids.

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction

None of the organic acids has been reported to cause carcinogenic, mutagenic or teratogenic effects. However, some derivatives of organic acids are suspected carcinogens.

V. Standards

Organic acid	ACGIH (TLV)
Acetic	10 ppm
Formic	5 ppm

VI. Environmental Data

None was available.

VII. Potential Exposure Estimates From National Occupational Hazard Survey

Adipic acid	less than 5,000
Acetic acid	1,000,000
Maleic acid	less than 5,000
Acrylic acid	60,000
Propionic acid	450,000
Benzoic acid	500,000
Phthalic acid	less than 5,000
Isophthalic acid	less than 5,000
Stearic acid	500,000

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ARENES

I. Description

The arenes are aromatic hydrocarbons having one or more benzene rings. Some of the industrially important arenes are:

Trimethyl benzene
- Mesitylene
- Pseudocumene

} isomers of trimethyl benzene

Cumene
Styrene
p-tert-butyl toluene
Alpha-methyl styrene
Xylidiene
Vinyl toluene

II. Production and Use

Available data indicate that atleast a few million pounds of pseudocumene is produced a year. The cumene production amounted to 1,139 million pounds from January to August in 1975. Styrene (monomer) production was 2,385 million pounds for the first eight months in 1975 (and 4,394 for the year 1975). The domestic demand was expected to increase about 11-14 percent during 1973-78. There was less than two million pounds of p-tert-butyl toluene produced in 1974. The production of Xylidine was 92,000 pounds back in 1945. Production of vinyl toluene was more than 50 million pounds in 1974.

The main uses of arenes are as solvents, intermediates in chemical synthesis of synthetic fibers, and as heat-transfer agents. Xylidine is used in making azo dyes.

The processes used in producing some arenes are as follows:

Xylene + nitrogen → nitroxylene reduction → xylidines
toluene + isobutylene → p-tert-butyl-toluene benzene +
propylene → cumene

Trimethyl benzene is produced by catalytic reforming or catalytic cracking processes.

The major producers of arenes in the U.S. are as follows:

Company	Millions of Pounds of Chemical (1973)
AMOCO Chem. Corp.	800 (Styrene)
Dow Chem. USA	1,550 (Styrene)
	50 (Binyl toluene)
Foster Grant Co., Inc.	750 (Styrene)
Monsanto Co.	1,300 (Styrene)
Shell Chem. Co.	< 2 (p-tert-butyl toluene)

III. Toxicity Information

Acute Exposure

Arenes are slight to moderately toxic to experimental animals. Arenes are considered to be hazardous particularly when in liquid form. They are primary irritants and cause dermatitis, pulmonary edema, pneumonitis and hemorrhage. They are also destructive to blood forming tissues.

In human subjects, exposed to styrene at 100 ppm for 1 hour, it produced a mild, untoward, but transient subjective response (unspecified) in half of those exposed. Mesitylene and cumene produce a narcotic effect in humans as well as in animals.

Chronic Exposure

The toxicity of arenes varies from slight to moderate in chronic exposures. Skin and eye irritation are the main symptoms. CNS and blood forming organs can also be affected.

In animals, cummulative effects in lung, liver and kidney may result after long exposure to cumene.

Other toxicity data for individual compounds in this class are as follows:

Trimethyl benzene

Mesitylene

Rat - inhalation, LCLO 2,400 ppm (24 hr.)
Rat - intraperitoneal, LDLO 1.5 g/kg
Guinea pig - LDLO 1.3 g/kg
Human - inhalation, TCLO 10 ppm

Cumene

Rat - oral, LD50 1.4 g/kg
Rat - inhalation, LC50 8,000 ppm
Mouse - inhalation, LD50 2,000 ppm (7 hr.)
Mouse - inhalation, LCLO 2,000 ppm

Styrene

Rat - oral, LD50 5.0 g/kg
Mouse - oral, LD50 0.22 g/kg
Human - inhalation, LCLO 10,000 ppm (30 months)
Rat - inhalation LCLO 5,000 ppm
Mouse - inhalation, LCLO 10,000 ppm
Guinea pig - inhalation, LCLO 12 g/m3 (14 hr.)
Human - inhalation, TCLO 376 ppm (CNS effect)
Human females - inhalation, TCLO 20 mg/m3 (glandular effect)

p-tert-butyl toluene

Human - inhalation, TCLO 10 ppm/3 minutes
Human - inhalation, TCLO 20 ppm/5 minutes
Rat - oral, LD50 1.5 g/kg
Rat - inhalation, LC50 1.5 g/m3/ 4 hours
Mouse - oral, LD50 0.9 g/kg
Mouse - inhalation, LC50 248 ppm/2 hours
Rabbit - oral, LD50 2.0 g/kg

Alpha-methyl styrene

Human - inhalation, TCLO 600 ppm
Rat - oral, LD50 4.9 g/kg
Rat - inhalation, LCLO 3,000 ppm
Guinea pig - inhalation, LCLO 3,000 ppm

Zylidine

Rat - oral, LDLO 0.6 g/kg
Mouse - inhalation, LCLO 149 ppm
Cat - i.v., LDLO 0.120 mg/kg
Rabbit - i.v., LDLO 0.24 g/kg

Vinyl toluene

Rat - oral, LD50 4.0 g/kg
Human - inhalation, TCLO 400 ppm

Produces eyes, nose and throat irritation and damage to kidney and liver.

IV. Standards

Mesitylene, TLV, ACGIH, 25 ppm (120 mg/cu m)
Styrene, TLV, ACGIH, 100 ppm (420 mg/cu m)
TWA, USSR, 12 ppm (50 mg/cu m)
Cumene, TLV, ACGIH, 50 ppm (250 mg/cu m)
p-tert-butyl toluene, TLV, 10 ppm (air)
Vinyl toluene, TLV, ACGIH, 100 ppm

V. Environmental Data

None available; no mention was made on the teratogenic, mutagenic and carcinogenic properties of arenes.

VI. Potential Exposure Estimates from the National Occupational Hazard Survey

Cumene	< 5,000
Ethyl benzene	25,000

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ALKENES

I. Description

The alkenes are a widely used class of unsaturated organic compounds possessing the double bond. This class of compounds has been defined to include the industrially important alkenes, alkadienes, cycloalkenes and cycloalkadienes. The following list includes available production figures:

	Millions of lbs.	Year
Butylenes (1-butene, 2-butene, isobutylene)	24,780	1974
Propylene	23,200	1974
Ethylene	20,852	1972
1,3-Butadiene	3,682	1974
Cyclohexene	2,298	
Isoprene (2-methyl-1, 3-butadient)	352	1970
Dicyclopentadiene	155 (capacity)	1974
Cyclopentadiene	100 (capacity)	1974
1-Heptene	70	1974
Diisobutylene	60	1974
Methylcyclopentadiene		
1,4-Hexadiene		
1-Pentene (amylene)		
Methylcyclohexene		

II. Production

Large quantities of alkenes are produced during petroleum refining operations. The volumes produced, and the quantity and availability of various isomers for petrochemical raw material use are determined, to a great extent, by the petroleum industry's captive needs. The alkenes do not occur in petroleum or natural gas, but are produced as by-products of the thermal and catalytic cracking of the higher molecular weight petroleum fractions. Some alkenes, such as the cycloalkenes and cycloalkadienes are also recovered as by-products of the coke-oven industry. In general, only the lower molecular weight alkenes (C_2-C_5) can be separated by distillation from each other and the saturated hydrocarbons present in the petroleum streams prepared by cracking. Alkenes can be manufactured by polymerization of lower molecular weight alkenes and other synthetic methods, as well as by cracking operations. The higher alkenes (greater than C_5) are often prepared by synthetic methods which result in the production of mixtures that are less complex than those found in gasoline and naphtha. When alkenes with particular structures or compositions are necessary, reactions such as polymerization, dehydrogenation, and dehydration of alcohols may be used. There are many companies producing alkenes in the U.S., and their manufacture is often associated with petroleum refining operations.

III. Uses

The alkenes are a widely used class of compounds. Ethylene finds some

specialized use as a refrigerant, a plant growth accelerator and fruit ripener, an anesthetic, and in welding and metal cutting operations. Alkenes are blended into gasolines because of their good anti-knock properties, and are also used in the manufacture of surfactants, plasticizers, perfumes, elastomers, varnishes, ferrocene compounds, paints and special solvents. This class of compounds includes some very important chemical building blocks and intermediates. Compounds such as isoprene, butadiene, and the butylenes have very important uses in the manufacture of synthetic rubber, plastics, and resins.

IV. Toxicity Information

A. Target organs: The major toxic effects of this class of compounds are on the skin, eyes, and mucous membranes of the respiratory tract. They may also exert effects on the lungs, kidney, liver, and central nervous system.

B. LD50 Values:

Ethylene:

Prolonged inhalation of 85% in oxygen is slightly toxic, resulting in a slow drop in blood pressure; 94% in oxygen is acutely fatal.

1,3-Butadiene:

Mouse - LD50 270 mg/kg
Rat - LD50 285 mg/kg
Human - inhal, LCLo 250,000 ppm/25 min

Small animals were exposed at 600 ppm, 2,300 ppm, or 6,700 ppm for 7.5 hours per day, 6 days per week, for 8 months. No significant, progressive injury was noted. Animals exposed at the highest concentration showed slightly retarded growth, and in some cases slight liver damage was observed. Humans exposed at 8,000 ppm for 8 hours exhibited no symptoms other than slight irritation of eyes and upper respiratory tract.

Cyclohexene:

Doses of 60-70 mg/kg are reported to be lethal to white mice.

Isoprene:

Mouse - inhal, LCLo 144 mg/cu m
Rat - inhal, LCLo 180 mg/cu m

A concentration of 5% in air is reported to be fatal to mice.

20,000 ppm - no narcosis in mice (2 hrs)
35,000-45,000 ppm - deep narcosis in mice
50,000 ppm - death in mice

Dicyclopentadiene:

Mouse - ip, LD50 200 mg/kg
Rat - ip, LD50 200 mg/kg
oral, LD50 410 mg/kg
inhal, LCLo 500 ppm
Rabbit - skin, LDLo 311 mg/kg

Doses of 1 ml/kg administered subcutaneously once a day for 14 days, and single doses of 5 ml/kg administered subcutaneously resulted in production of leukocytosis in rats.

Cyclopentadiene:

Human - inhal, TCLo 250 ppm - lowest published toxic concentration at which irritant effects are observed.

Rats exposed to 35 repeated 7 hour exposures during a period of 53 days at an average concentration of 500 ppm suffered mild injury to the liver and kidneys.

C. Acute/subchronic effects:

The alkenes generally exhibit the properties of simple asphyxiants and weak anesthetics with rapid action and rapid recovery and anesthetic potency tends to increase with increasing chain length. At increasingly higher concentrations of alkenes in air , the narcotic effects exhibited include fatique, drowsiness, headache, vertigo, loss of consciousness, paralysis, and possibly death. Other effects of very high concentrations of alkenes reported in animal studies are malfunctions of heart, depressed activity of sympathetic ganglion of the upper neck, increased blood coagulation time, and disturbances of the electrical activity of the brain. The higher alkenes may cause cramps, cyanosis, and paralysis following administration, and in these cases the narcotic dose approaches the toxic dose.

Vapors of the alkenes tend to irritate the eyes, skin, and mucous membranes of the nose, throat, and respiratory tract. The vapors may irritate the bronchi and lungs, producing coughing. Alkenes may produce a primary irritant type of contact dermatitis and exert a general irritant and defatting action on the skin. In addition, the lower alkenes may produce cold injury such as "freezing burns" or frostbite as a result of contact with the liquid or evaporating gas.

The cycloalkenes and cycloalkadienes appear to be the most toxic compounds in this class. They tend to have similar actions to the alkenes in general, although they are more potent. Dicyclopentadiene is reported to have toxic effects typical of the irritating hydrocarbons when administered orally in large doses. These effects include generalized congestion, hyperemia, and focal hemorrhage in many tissues such as the kidneys, intestine, stomach, bladder, and lungs.

D. Long-term effects:

Chronic exposure to alkenes produces effects related to their irritant and narcotic properties. These effects include irritation of the eyes, skin, and mucous membranes, headache, and drowsiness. Prolonged exposure to the lower alkenes at sufficiently high concentrations may cause permanent damage due to oxygen deprivation. Some of the systemic effects reportedly due to chronic exposure to ethylene are lung inflammation, histopathological changes in the liver and cerebellum, peripheral leukopenia, reduced cellularity of the bone marrow, hypertension, and inhibition of cholinesterase activity. Diisobutylene has been reported to cause liver and kidney damage, while chronic exposure to cyclopentadiene may result in abdominal pain, jaundice, and anemia. There are relatively few reports of chronic or cumulative effects of exposure to alkenes, partially due to the fact that they are rapidly eliminated from the systems of exposed animals and humans.

E. Carcinogenicity, Mutagenicity, Teratongenicity, and Other Effects on Reproduction:

One report mentions that heptene (unspecified isomer) is a potential carcinogen according to the Environmental Protection Agency. No other reports of carcinogenicity, mutagenicity, or teratogenicity as a result of exposure to alkenes were identified.

F. Epidemiologic Studies:

Few, good epidemiologic studies concerning occupational exposure to alkenes appear to have been conducted. However, many sources report that, in general, workers' health will not be jeopardized by exposure to low concentrations for prolonged periods, or to higher concentrations for relatively short periods of time.

V. Standards

The following are Threshold Limit Values for Chemical Substances in Workroom Air Adopted by ACGIH (1976):

Butadiene	1,000 ppm	2,200 mg/cu m
Methylcyclohexene	400 ppm	1,600 mg/cu m
Cyclohexene	300 ppm	1,015 mg/cu m
Cyclopentadiene	75 ppm	200 mg/cu m
Dicyclopentadiene	5 ppm	30 mg/cu m
Ethylene	*	
Propylene	*	

*These compounds are classified as simple asphyxiants by ACGIH. A TLV is not recommended for these compounds because the limiting factor is the availability of oxygen in the air. In general, it is recommended that at normal atmospheric pressure the oxygen content of the air should not be less than 18%.

VI. Environmental Data

Because of their volatility and flammability, the alkenes present moderate to severe fire and explosion hazards. Care must be taken to prevent explosive mixtures from accumulating in the air. The appropriate precautions for such hazards must be taken in their industrial handling and storage. In addition, some of the alkenes may react violently with oxidizing materials or form explosive peroxides (in the absence of inhibitors) with air. For these reasons, and to prevent asphyxiating concentrations from accumulating in air, proper ventilation must be provided.

Inhalation of irritating vapors, and "freezing burns" from skin contact with liquid and evaporating vapors may also be hazards in the work area. Impervious hand, eye, and face protection, as well as respirators and protective clothing should be provided when necessary.

Many manufacturing processes involving alkenes take place in a closed system and thus offer less opportunity for occupational exposure. Since exposure may often result due to a leak, spill, or other accident, care should be exercised in handling and storage of alkenes and maintenance of equipment. Workers should be aware of hazards and emergency actions in the event that an accident occurs.

Identification of Informational Gaps

Industrial experience with alkenes does not seem to indicate any serious health effects. Epidemiological studies of occupational exposure to alkenes and laboratory experiments should be undertaken to study some of the more widely used or hazardous compounds. Data concerning human response to various atmospheric concentrations, and repeated inhalation studies for many important alkenes are lacking.

VII. Potential Exposure Estimates from the National Occupational Health Survey

Unclassified Alkenes		2,000,000
1,3-Butadiene		60,000
Ethylene		35,000
Isoprene		35,000
1-Butene	less than	5,000
2-Butene	less than	5,000
Propylene	less than	5,000
Dicyclopentadiene	less than	5,000
Cyclopentadiene	less than	5,000
1-Pentene (amylene)	less than	5,000
1,4-Hexadiene	less than	5,000
Cyclohexene	less than	1,000

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BROMINATED ALIPHATICS

I. Description

A review of the available literature indicated that the following brominated aliphatic compounds are industrially important.

Methyl bromide
Bromochloropropane
    1-bromo-3-chloropropane
    1,2-dibromo-3-chloropropane
Bromochloromethane
Ethyl bromide
Acetylene tetrabromide
Bromotrifluomethane
Methylene bromide
Dibromochloropropane

II. Production and Use

The production of brominated aliphatic compounds amounted to 6.82 short tons in 1974. Consumption figures were not available for individual chemicals with the exception of methyl bromide, of which the annual consumption for 1975 was 20 million pounds. It was projected that the consumption of methyl bromide would increase.

The major uses of brominated aliphatics include flame retardants in fibers, plastics, foams, and fire extinguishing fluid. Other uses for individual compounds are as follows:

> Methyl bromide is used as a pesticide and in soil fumigants. Bromochloropropane is used in pharmaceuticals, as well as in soil fumigants. Ethyl bromide is used as an anesthetic, refrigerant, solvent and fumigant for fruit and grain. Acetylene tetrabromide and bromoform have been used as heavy liquids for mineral or other solid separations, as fluid in liquid gauges, and as solvents for fats and waxes.

The two processes of production of brominated aliphatics are: (1) Bromination, (2) Replacement of chlorine from chlorides. In both processes, distillation has commonly been used for separation of the brominated aliphatics.

Several companies in this country have been major producers of bromine and bromine compounds. Their annual production figures are:

Company	Millions of Pounds of Bromine and Bromine Compounds
Dow Chemical, USA	205
Ethyl Corporation	160
Great Lakes Chem. Corp.	140
Northwest Corporation	30

III. Toxicity Information

Acute Exposure

The acute toxicity of this group of compounds generally encompasses irritation to the skin, mucuous membrane of eyes and nose ; they affect the CNS, internal organs, liver, lungs and kidneys.

The toxicity, however, ranges from very toxic compounds as in methyl bromide, to slightly toxic as in methylene bromide.

Chronic Exposure

In animal experimentation, paralysis of extremities and pulmonary damage have been observed. In humans, the chronic effects of methyl bromide have been nausea, vomiting and headache after a 35 ppm exposure for two weeks. Severe lung irritation can also develop.

Methyl bromide - after severe exposure, CNS symptoms, followed by convulsions, muscular tremors, and death can occur.

Rat - inhalation, LC50 21 mg/liter
Rat - inhalation, LCLO 514 ppm (6 hours)
Guinea pig - inhalation, LCLO 300 ppm (9 hours)

Bromochloropropanes

1-bromo-3-chloropropane
- moderately toxic by inhalation
1,2-dibromo-3-chloropropane
- strong irritant to skin, eyes and throat

Bromochloromethane

Mice - inhalation, LD50 2,273 ppm/7 hr.

Ethyl bromide

Rat - inhalation, LDLO 16,700 ppm/15 minutes
Guinea pig - inhalation, LCLO 2,200 ppm

Acetylene tetrabromide

Rabbit - oral, LD50 0.4 g/kg
Guinea pig - oral, LD50 0.4 g/kg
- may cause narcosis and coma and eventually death

Bromotrifluoromethane

Rat - inhalation, LCLO 834,000 ppm/15 minutes

Bromoform

Mouse - subcutaneous, LD50 1.8 g/kg
Rabbit - subcutaneous, LDLO 0.4 g/kg

IV. Standards

For methyl bromide a TLV of 15 ppm, for ethyl bromide a TLV of 200 ppm, for acetylene tetrabromide a TLV of 1 ppm and bromoform a TLV of 0.5 ppm has been recommended by the ACGIH. All these standards, with the exception of ethyl bromide, have skin designations.

V. Environmental Data

None available.

VI. Potential Exposure Estimated from the National Occupational Hazard Survey

Methyl bromide	75,000
Bromochloropropane	< 1,000
Ethyl bromide	< 1,000

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ALCOHOLS

I. Description

Alcohols are an important and widely used hydroxyl-containing class of compounds with the general formula ROH. This class has been defined to include industrially important primary alcohols (excluding methanol, isopropanol, ethanol, furfuryl alcohol, and phenols.) The following list includes available production figures:

	Million Pounds	Year
Cyclohexanol	716.9	1973
n-butanol	557.6	1975
2-ethyl hexanol	395	1974
Decyl alcohol	152.5	1968
Isobutyl alcohol	96.4	1972
Isooctyl alcohol	85	1965
n-propanol	83.1	
n-amyl alcohol	12-15	1962
Benzyl alcohol	10.4	1972
Propargyl alcohol (2-propyn-1-ol)	6-8	1974
Phenylethyl alcohol (2-phenolethanol)	1.75	1962
Detergent range alcohols (C 11 and up)	521-555	1970
lauryl alcohol		
myristyl alcohol		
cetyl alcohol		
stearyl alcohol		
Plasticizer range alcohols (C 6 to C 11)	255	1970
Allyl alcohol (2-propen-1-ol)		
2-methyl-1-butanol		
3-methyl-1-butanol		
2-ethylbutyl alcohol		
1-hexanol		
2,2,4-trimethyl-1-pentanol		
1-octanol		
Nonyl alcohol		
Methylcyclohexanol		

This class of compounds containing alcohols possesses a wide range of chemical and physical properties. The C_1 - C_4 alcohols are mobile liquids, the C_5 - C_{11} alcohols are oily liquids, and the C_{12} and higher alcohols are usually solids. The higher alcohols (C_6 - C_{27}) have been classified as plasticizer-range alcohols (C_6 - C_{11}) and detergent range alcohols (C_{11} and up) to reflect their industrial usage. Specific examples of these alcohols are also included in the preceding list.

II. Production

There are very many production processes and producing companies associated with the manufacture and use of alcohols and alcohol containing products. The detergent range alcohols (C_{11} and up) are usually consumed industrially as mixtures of alcohols and their purity is rarely of great commercial importance. They are generally straight-chain, primary alcohols with an even number of carbon atoms. These alcohols are most often produced by conversion of natural fats and oils (coconut oil, tallow) by processes such as the saponification of esters and the reduction of esters. The plasticizer range alcohols (C_6 to C_{11}) may also be produced from natural products. More often the plasticizer range and lower alcohols are produced synthetically from petroleum derived raw materials. Greater control over the final purity of the alcohols produced can be exerted using synthetic processes such as Aldol condensations, the Oxo (hydroformylation) Reaction, and production of linear primary alcohols from ethylene via Ziegler Chemistry. There are many specific processes that may be used to vary the purity and composition of the final product.

III. Uses

There are many different industrial uses for alcohols and much overlap of uses among the various alcohols. The C_{11} and higher alcohols are used primarily for the production of detergents. They are also used in organic synthesis and in the manufacture of surfactants, cosmetics, perfumes, lotions, and lubricant additives. The C_6 to C_{11} alcohols are mainly used for the production of plasticizers, but also find usage in detergents, organic synthesis, solvents, lubricant additives, surfactants, lacquers, dyestuffs, color photograph processing, perfumes, cosmetics, textiles, antibacterial agents, and anti-foaming agents. The lower alcohols are used in organic synthesis and in the manufacture of lacquers, paints, varnishes, paint removers, plastics, explosives, hydraulic fluids, perfumes, solvents, photographic chemicals, flavorings, cosmetics, cleaners, and antibacterial agents.

IV. Toxicity Information

A. Target organs: The major toxic effects of this class of compounds are on the skin, eyes, and respiratory tract. Alcohols may also cause harmful effects in the heart, liver, kidneys, lungs, and central nervous system.

B. LD50 values:

Cyclohexanol

Rat - oral, LD50 2060 mg/kg
Rabbit - oral, LDLO 2200 mg/kg
Human - inhalation, TCLO 100 ppm - lowest published concentration at which mucous membrane effects are observed

Butyl alcohol

Rat - oral, LD50 790 mg/kg
Rabbit - oral, LDLO 4250 mg/kg
Human - inhalation, TCLO 25 ppm - lowest published concentration at which pulmonary system effects are observed

2-ethylhexanol

Rat - oral, LD50 3200 mg/kg
Rabbit - skin, LD50 2380 mg/kg

Decyl alcohol

Mouse - inhalation, LC50 4000mg/cu m
Rat - oral, LD50 4720 mg/kg

Isobutyl alcohol

Rat - oral, LD50 2460 mg/kg
Rat - inhalation, LDLO 8000 ppm/4 hr
Rabbit - skin, LD50 4240 mg/kg

Isooctyl alcohol

Rat - oral, LD50 1480 mg/kg

Propyl alcohol

Rat - oral, LD50 1870 mg/kg
Rat - inhalation, LCLO 4000 ppm/4 hr
Woman - oral, LDLO 5700 mg/kg

N-amyl alcohol

Mouse - oral, LD50 200 mg/kg
Rat - oral, LD50 3030 mg/kg

Benzyl alcohol

Mouse - oral, LD50 1580 mg/kg
Rat - oral, LD50 1230 mg/kg
Rat - inhalation, LC50 1000 ppm/8 hr
Rabbit - oral, LD50 1940 mg/kg

Propargyl alcohol

Mouse - inhalation, LCLO 2000 mg/cu m
Rat - oral, LD50, 70 μg/kg

Phenylethyl alcohol

Mouse - oral, LD50 800 mg/kg
Rat - oral, LD50 1790 mg/kg
Rabbit - skin, LD50 790 mg/kg

Allyl alcohol

Mouse - oral, LD50 96 mg/kg
Rat - oral, LDLO 69 mg/kg
Rat - inhalation, LC50 165 ppm/4 hr
Rabbit - oral, LDLO 53 mg/kg
Rabbit - skin, LDLO 53 mg/kg
Rabbit - inhalation, LCLO 1000 ppm/4 hr
Monkey - inhalation, LCLO 1000 ppm/4 hr
Human - inhalation, TCLO 25 ppm - lowest published toxic concentration at which irritant effects are observed

2-methyl-1-butanol

Rat - oral, LD50 4920 mg/kg
Rabbit - skin, LDLO 3540 mg/kg

3-methyl-1-butanol

Rat - oral, LD50 1300 mg/kg
Rabbit - oral, LDLO 4250 mg/kg
Rabbit - skin, LD50 3970 mg/kg

2-ethylbutanol

Rat - oral, LD50 1850 mg/kg
Rabbit - oral, LD50 1200 mg/kg
Rabbit - skin, LD50 1260 mg/kg

Methylcyclohexanol

Rabbit - oral, LDLO 1750 mg/kg

Octyl alcohol

Mouse - oral, LD50 1790 mg/kg

C. Acute/subchronic effects: The saturated alcohols are generally considered to possess low to moderate toxicity in an industrial setting, although the corresponding unsaturated alcohols tend to be much more toxic. Only the lower and middle range alcohols seem to present potentially serious occupational hazards. Inhalation of concentrations of vapors resulting in toxic effects is mainly a problem with the more volatile lower alcohols. The lower and middle range alcohols may cause toxic effects resulting from skin contact and absorption through the skin of liquid alcohols. Industrial poisonings due to ingestion of alcohols are reported to generally be due to intentional ingestion by workers.

Alcohol vapors tend to irritate the eyes, the skin, and the mucous membranes of the nose, throat, and upper respiratory tract. Eye contact with the vapors of alcohols may result in the appearance of translucent vacuoles in the superficial layers of the cornea. Some of the more severe signs of intoxication due to exposure to high vapor concentrations of alcohol that have been reported include headache, vertigo, nausea, diarrhea, drowsiness, pulmonary irritation and congestion, restlessness, visual disturbances, ataxia, prostration, and central nervous system depression.

In animal studies it has been shown that ingestion of alcohols may lead to severe vascular damage and severe damage to the myocardium, lungs, liver, kidneys, and brain. If the dose is high enough, intoxication proceeds to narcosis and eventually death. Some studies have indicated that the primary cause of death is due to cardiovascular failure which probably occurs as a result of depression of the respiratory and vasomotor centers, and a decrease in the effective blood pressure. Aspiration of lower molecular weight alcohols into the lung is reported to cause pulmonary edema and hemorrhage.

Alcohols may produce mild to very strong irritant effects as a result of contact with the skin. Skin contact with alcohols (especially lower molecular weight and unsaturated alcohols) may cause erythema or dermatitis due to removal of protective skin lipids and dehydration. Prolonged contact with certain alcohols (allyl, propargyl) may cause severe burns to the eyes and skin. Some alcohols (allyl) are readily absorbed through the skin. Large doses of allyl alcohol absorbed through the skin of rabbits have produced tremors, narcosis, hypothermia, and death. Other symptoms of systemic intoxication due to absorption of alcohols through the skin include deep pain (probably due to muscle spasm), double vision, deafness, and delirium. Delayed eye irritation and muscle spasm may also result from skin contact and absorption.

D. Long term effects: Prolonged and repeated contact with excessive alcohol vapors in air is reported to cause irritation to the eyes, membranes of the upper respiratory tract, and the bronchi. Other symptoms of chronic intoxication include headache, formation of vacuoles in the superficial layers of the cornea, loss of weight, loss of appetite, lacrimation, salivation, lethargy, incoordination, narcosis, and mild convulsions. It has been demonstrated in animal experiments that death may result under the appropriate conditions.

Repeated skin contact with lower molecular weight alcohols may cause dermatitis in varying degrees of severity depending on the particular alcohol involved, and the extent of exposure. Repeated absorption of large amounts of alcohols through the skin may result in tremors, narcosis, hypothermia, weakness, deep anesthesia, local petechiae, gross hemorrhage, and thickening of the skin.

In experimental animal studies, chronic ingestion of alcohols has been shown to cause varying degrees of damage to the blood vessels, liver, lungs, kidneys, central nervous system, and heart. In addition, it has been demonstrated that comparable toxic lesions may be produced in the tissues of animals that have been subjected to the inhalation of vapors and the percutaneous absorption of alcohols

E. CMT and other effects on reproduction: There are no reports available concerning carcinogenicity, mutagenicity, or teratogenicity as a result of exposure to alcohols.

F. Epidemiologic studies: Epidemiologic studies showing that excessive vapor concentrations of butyl alcohol cause lacrimation, photophobia, visual disturbances, and corneal irritation with production of vacuoles in the corneal epithelium. It was shown that these effects were no longer observed when vapor concentrations of alcohol were reduced to appropriate levels. In general, there are very few reports of occupational hazards or ill effects associated with the use of alcohols in an industrial setting.

V. Standards

The following are the Threshold Limit Values for Chemical Substances in Workroom Air adopted by ACGIH (1976):

	TWA	
	ppm	mg/cu m
Cyclohexanol	50	200
n-butanol - skin	50	150
Isobutyl alcohol	50	150
Propyl alcohol - skin	200	500
Propargyl alcohol - skin	1	2
Allyl alcohol - skin	2	5
Methylcyclahexanol	50	235

VI. Environmental Data

Because of their flammability and volatility, alcohols may represent moderate to severe fire and explosion hazards. The appropriate precautions should therefore be taken in their industrial use and storage.

The proper precautions should also be taken to prevent injury resulting from contact with alcohols in liquid and vapor form. Adequate ventilation should be provided when appreciable concentrations of vapor may be encountered in order to safeguard against fire and explosion as well as exposure at excessive vapor concentrations. Respirators and protective clothing and equipment may be necessary to prevent inhalation of vapors and contact of liquid with skin.

Identification of informational gaps: Industrial experience with alcohols does not seem to indicate any long-term, serious health effects. More comprehensive and rigorous epidemiological studies of occupational exposures to alcohols should be undertaken. Since industrial usage of alcohols is so widespread and varied, it might be useful to catalogue more accurately the types of processes they are involved in and the identity and number of workers potentially exposed.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Unclassified alcohols	1,000,000
n-butanol	2,100,000
n-propyl alcohol	1,300,000
Isobutyl alcohol	500,000
n-amyl alcohol	100,000
Benzyl alcohol	25,000
Allyl alcohol	less than 5,000
2-ethylhexanol	less than 5,000

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GLYCOLS

I. Description

Glycols are compounds having two hydroxyl groups attached to carbon atoms in an aliphatic chain. Following glycols are of industrial importance:

Compound	CAS No.
Ethylene glycol	000107211
Diethylene glycol	000111466
Triethylene glycol	000112276
Propylene glycol	000057556
Dipropylene glycol	000110985
1,3-Butylene glycol	000107880
1,4-Butylene glycol	000110634
Neopentyl glycol	000126307
Hexylene glycol	000107415
Trimethylpentanediol	000144194

Polyethylene glycols, polypropylene glycols and mixed polyethylene-polypropylene glycols are also industrially important but are excluded here. *

Physical and Chemical Properties:

Glycols have physical and chemical properties intermediate between monohydric alcohols and glycol. Those derived from up to a seven-carbon hydrocarbon are generally miscible with water in all proportions at 20°C. The lower glycols are hygroscopic, and act as good solvents for many resins, oils, dyes and natural gums. The chemistry of the glycols is centered around the two hydroxyl groups, and is largely common to that of the simple alcohols. Derivatives, such as esters, acetals, ketals, and aldehydes are readily formed from these compounds.

II. Production

Manufacturing Processes:

The major process used in the manufacture of ethylene glycol is oxidation of ethylene oxide and subsequent hydration of the oxide to form the glycol. A new process which has been developed by Halcon International involves the reaction of ethylene with acetic acid in the presence of a catalyst to form mono- and diacetates. These products are then hydrolyzed to ethylene glycol. Oxirane Corporation is planning to use this process in a new plant due to begin production in 1977.

Diethylene glycol and triethylene glycol are normally produced as by-products of ethylene glycol production. The proportion of these glycols produced is controlled by the molar ratio of ethylene oxide to water. A higher ratio of polyglycols is produced at higher molar ratios of ethylene oxide to water.

* As directed by NIOSH

Propylene glycol is produced by hydration of propylene oxide.

Dipropylene glycol is obtained as a by-product of propylene glycol manufacture or by the addition of propylene oxide to propylene glycol.

The chief source of commercial 1,3-butylene glycol is catalytic hydrogenation of acetaldol. Aldol for synthesis of 1,3-butylene glycol is usually prepared by self-condensation of acetaldehyde in an aqueous alkaline solution.

1,4-Butylene glycol is manufactured as one of the products in the production of polyvinylpyrolidone (PVP). Acetylene is reacted with formaldehyde to form 1,6-butynediol which is hydrogenated to produce 1,4-butylene glycol.

Neopentyl glycol is produced by a crossed Cannizzaro reaction of isobutyraldehyde with two moles of formaldehyde.

Flexylene glycol is produced commercially by catalytic hydrogenation of diacetone alcohol.

Trimethylpentanediol can be produced by hydrogenation of the aldehyde trimer resulting from the aldol condensation of isobutyraldehyde.

Manufacturers:

The following companies were producing ethylene glycol as of June, 1976:

1) BASF Wyandotte Corporation
2) Calcasieu Chemical Corporation
3) Celanese Corporation
4) Dow Chemical USA
5) Northern Natural Gas Company
6) Olin Corporation
7) PPG Industries, Inc.
8) Shell Chemical Company
9) Texaco Inc.
10) Texas Eastman Company
11) Union Carbide Corporation

In addition, Oxirane Corporation is constructing an 800 million lb/yr plant scheduled to be on stream in late 1977. Union Carbide is building a 700 million lb/yr plant in Texas City, TX (completion in 1979).

As of April 15, 1974, the following companies produced propylene glycol:

1) Dow Chemical USA
2) Jefferson Chemical Company, Inc.
3) Olin Corporation
4) Oxirane Corporation
5) Union Carbide Corporation

The GAF Corporation in Texas City, Texas, now produces 1,4-Butylene glycol and the BASF Wyandotte Corporation in Geismar, Louisiana, produces 1,4-Butylene glycol.

Neopentyl glycol is manufactured by the Texas Eastman Company.

Production: (millions of pounds)

Compound	Year	Production	Production Trends
Ethylene glycol	1974	3,340.7	increasing
Propylene glycol	1974	510.2	increasing
Diethylene glycol	1974	309.3	increasing
Triethylene glycol	1974	110.5	increasing
Dipropylene glycol	1974	52.95	increasing

Production figures are not readily available for neopentyl glycol, however, the estimated demand for neopentyl glycol as an intermediate of unsaturated polyester for 1976 is 10.1 million pounds. Also, the consumption of 1,4 butylene glycol for use in polyurethane production is approximately 5 million pounds.

III. Uses

Ethylene glycol is used primarily in low volatility permanent-type antifreeze for liquid cooled motor vehicles, and in the production of polyethylene terephthalate fibers and films. The latter represents the fastest growing end use for ethylene glycol. Ethylene glycol is also a component in aircraft deicing fluids, fire-resistant water-glycol hydraulic fluids (hydrolubes), and modern automotive brake fluids. Inhibited ethylene glycol can be used as a high temperature coolant for internal combustion stationary engines, snow melting systems, industrial heat transfer systems and refrigeration systems where corrosion by brine solutions is a problem. Ethylene glycol is also used in solvent systems for paints, varnishes and stains.

Diethylene glycol and triethylene glycol are used for many of the same applications, such as natural gas dehydrants, in polyurethanes, and as solvents; other uses of diethylene glycol are: as a precursor of triethylene glycol automotive brake fluids, lubricants, inks, mold release agents, adhesives, paper, packaging materials and coatings, and as an intermediate in the production of diethylene glycol dinitrate, and diethylene glycol esters and ethers. In addition, triethylene glycol is used in air conditioning systems to aid in the control of the bacteria and virus content of air and in the dehumidification of air.

The largest market for propylene glycol is as an intermediate for unsaturated polyester resins and is expected to grow approximately 11-13% from 1974-1979. "Miscellaneous applications" include uses such as a solvent for food flavorings, colorants, and drugs and an ingredient in the preparation of medicines and pet foods. Propylene glycol is also used as a preservative, softening agent, lubricant for food machinery, heat transfer fluid for processing of foods, and as an ingredient in cosmetics and antifreeze.

Dipropylene glycol is consumed primarily in the production of unsaturated polyester resins and plasticizers. In 1972, 30 million pounds of dipropylene glycol were consumed for this purpose. This compound is also used in the production of alkyd resins and printing inks and in the extraction of aromatic hydrocarbons by the Udex process. Use as an Udex extraction solvent may decrease as use of sulfolane for extraction grows, however.

The uses of 1,3- utylene glycol include: an ingredient of heavy duty brake-fluid formulations, a gelling agent for gelatin and similar proteins, a gelling agent for cellulose nitrate, a stabilizer for pharmaceuticals, and an intermediate in the manufacture of polyester plasticizers. Relatively small amounts are used in applications such as a humectant for plastic films used on food stuffs and for tobacco. It has been authorized by the FDA to be used as a solvent for natural and synthetic flavoring substances. 1,3-butylene glycol is also an ingredient in soaps, detergents, printing inks, and copying paper formulations.

The consumption growth of 1,4-butylene glycol is tied mainly to polyester use, especially for automobiles. This compound is also used in the production of polyurethanes, plasticizers, elastomers, surface coatings, softeners and moisteners for gelatin, cellophane, and specialty papers.

Neopentyl glycol can be used in the manufacture of polyesters used as plasticizers,polyurethane foams and elastomers, polyester thickening agents for synthetic lubricants, and alkyd resins.

Hexylene glycol is a freezing point depressant and is used as an anti-icing additive for gasoline. It is also used in hydraulic brake fluids, as a solvent for printing ink, as an additive to cement and as a chemical intermediate.

Trimethylpentanediol has applications in the automotive, textile, pharmaceutical, surface coating, plastic, and petroleum industries. Unsaturated polyesters derived from trimethylpentanediol are candidates for use in the manufacture of reinforced plastics. Several diesters, mixed esters, and polyesters of this compound show promise for use as plasticizers in the surface coatings, plastic film, and sheeting industries. It also can be used as a binder solvent for printing inks and as a thickening agent for synthetic lubricants.

IV. Toxicity Information

Both ethylene glycol and diethylene glycol are depressants of the central nervous system when administered in large doses. Non-fatal acute exposure to ethylene glycol may result in effects primarily on the kidney and brain and to a lesser degree on the liver. Such exposures to diethylene glycol may result in changes primarily in the kidneys and to a lesser extent in the liver. Long term effects from chronic exposure are most likely centered in the kidneys for ethylene glycol and in the kidneys and liver for diethylene glycol. Prolonged and repeated exposure to ethylene glycol has also resulted in symptoms of nystagmus, loss of appetite, "dopiness", and periods of unconsciousness. Triethylene glycol is very low in both acute and chronic oral toxicity. Monkeys and rats exposed to 1 ppm triethylene glycol for prolonged periods showed no physiologic effects. Ethylene, diethylene, and triethylene glycols produce no significant irritation of the skin. However, prolonged contact with any of the three compounds may result in a macerating action on the skin. None of these compounds caused appreciable irritation when introduced into the eyes of rabbits. Hazardous amounts of ethylene and diethylene glycol may be absorbed through the skin, though data supporting this is inconclusive. No studies were reported in the references used pertaining to the skin absorption of triethylene glycol.

The systemic toxicity of propylene glycol is especially low and it presents negligible hazards to health. Animals and humans have been exposed to saturated and supersaturated atmospheres without deleterious effects. Generally, this substance produces no significant skin irritation, but may cause primary skin irritation in some individuals, possibly due to dehydration. Propylene glycol, however, does not appear to be a sensitizer. Because of its low systemic toxicity, it is impossible for propylene glycol to be absorbed through the skin in hazardous amounts. It has been used widely in preparations for topical application with no adverse effects. This substance has produced no effects in the eyes of humans or rabbits. Pharmacologically, propylene glycol is a sedative. It is also glycogenic, entering into normal carbohydrate metabolism probably through the intermediate, lactic acid.

Dipropylene glycol is more active physiologically than propylene glycol, but is still of very low toxicity. It caused negligible irritation to the skin of rabbits when applied for prolonged periods and there was no indication that hazardous quantities were absorbed through the skin.

1,3-Butylene glycol appears to be very low in oral toxicity when administered as a single dose or in repeated doses. The LD50 is approximately the same as that for propylene glycol. Long term feeding of rats has shown no effects. The animals actually ate more and utilized food better when part of the caloric intake was supplied by 1,3-butylene glycol. Mice injected iv with 1,3-butylene glycol were protected from metrazole convulsions, and their electroshock threshold was raised. Acute intoxication results in deep narcosis. This compound was not irritating to the skin or eyes of rabbits nor to the skin or mucous membranes of humans.

1,4-Butylene glycol is approximately ten times as toxic when given to animals as 1,3-Butylene glycol. It causes deep narcosis, constriction of pupils, total loss of reflexes, and kidney injury. Death caused by administration of 1,4-Butylene glycol is attributable to paralysis of vital centers. Animals that survive the effects of this substance recover completely. When applied to the eyes of rabbits, it causes slight conjunctival irritation. There were no effects, however, when applied to abraded or intact skin of rabbits; nor was there evidence of absorption of acutely hazardous amounts. When administered orally to rabbits, most of the 1,4-Butylene glycol appears to be destroyed but small amounts of the corresponding acid are found in the urine.

Hexylene glycol is low in single dose oral toxicity. It is appreciably injurious to the eyes however. When introduced into the eyes of rabbits, it produced irritation and corneal injury that was slow to heal. Hexylene glycol is also irritating to the skin, but is not readily absorbed. Rats exposed to an atmosphere saturated at room temperature for 8 hours all survived. Such an atmosphere is detectable by odor and may be irritating to the eyes. This compound is a hypnotic, and is excreted slowly by humans, largely as the glucuronic acid conjugate.

Toxicity information for neopentyl glycol and trimethylpentadiol is given in the attached toxicity tables.

V. Standards

Ethylene glycol, ACGIH TLV, 1976:

Particulate, 10 mg/cu m

Vapors, 100 ppm (260 mg/cu m)

VI. Environmental Data

None available.

VII. Potential Exposure Estimates from National Occupational Hazard Survey

Miscellaneous glycols 3.2 million

TOXICITY TABLE

Ethylene glycol

Human, oral, 1500 mg/kg, LDLo

Rat, inhl, 0.5 mg/l (28hr), slight narcosis

Rat, inhl, 140-160 ppm, (8hr/d for 16 wk), no effect

Rat, oral, 5840 mg/kg, LD50

Rat, oral-diet, 1-2%, (2yr), shortened life span, bladder stones, severe renal injury, liver degeneration

Rat, subcut, 5300 mg/kg, LD50

Mouse, oral, 7500 mg/kg, LD50

Mouse, oral-water, 1-20%, strong diuretic effect, narcosis, central depression of heart and respiration

Mouse, subcut, 2700 mg/kg, LDLo

Mouse, iv, 3000 mg/kg, LD50

Cat, oral, 2000 mg/kg, LD50

Cat, subcut, 2000 mg/kg, LDLo

Rabbit, ip, 1000 mg/kg, LDLo

Guinea pig, oral, 6610 mg/kg, LD50

Guinea pig, subcut, 5000 mg/kg, TDLo

Diethylene glycol

Human, oral, 1000 mg/kg, LD50

Rat, oral-diet, 1%, (2yr), bladder tumors and bladder stones

Rat, oral-diet, 2%, (2yr), bladder tumors and bladder stones

Rat, oral-diet, 4%, (2yr), bladder tumors and bladder stones

Dog, oral, 9000 mg/kg, LD50

Cat, oral, 3300 mg/kg, LD50

Rabbit, iv, 2000 mg/kg, LD50

Triethylene glycol

Rat, oral, 22060 mg/kg, LD50

Rat, oral-water, 3%, (30d), no effect

Rat, oral-water, 5%, (30d), deleterious effects

Rat, ip, 8150 mg/kg, LD50

Rat, im, 8400 mg/kg, LD50

Propylene glycol

Rat, oral, 21000 mg/kg, LD50
Rat, oral-water, 10%, (140 d), no effect
Rat, oral-water, 25%,50%, (69d), death
Rat, oral-diet, 40%,50%,60%, (-), death
Rat, ip, 13000 mg/kg, LD50
Rat, subcut, 23000 mg/kg, LDLo
Rat, iv, 6800 mg/kg, LDLo
Rat, im, 20000 mg/kg, LD50
Mouse, oral, 24000 mg/kg, LD50
Mouse, ip, 11400 mg/kg, LD50
Mouse, subcut, 18500 mg/kg, LD50
Mouse, iv, 8000 mg/kg, LD50
Dog, oral, 22000 mg/kg, LD50
Dog, oral-water, 5%-10%, (5-9mo), no effects
Rabbit, oral, 19000 mg/kg, LDLo
Rabbit, oral, iv, 4200 mg/kg, LDLo
Rabbit, im, 6300 mg/kg, LDLo
Guinea pig, oral, 1900,mg/kg, LD50

Dipropylene glycol

Rat, oral, 14800 mg/kg, LD50
Rat, oral-water, 5%, (77d), no effects
Rat, oral-water, 10%, (77d), liver and kidney damage; death

1,3-Butylene glycol

Rat, oral, 22800 mg/kg, LD50
Rat, oral-water, 20%, (44d), no effect or slight depression of growth
Rat, oral-water, 10%, (-), no effect
Rat, oral-diet, 5600 mg/kg/d, (90d), no effect
Guinea pig, oral, 11000 mg/kg, LD50

1,4-Butylene glycol

Rat, oral, 1000 mg/kg, LD0

Rat, oral, 1780 mg/kg, LD50

Rat, oral, 4000 mg/kg, LD100

Rat, ip, 1370 mg/kg, LD50

Mouse, oral, 2062 mg/kg, LD50

Mouse, ip, 500 mg/kg, LDLo

Rabbit, oral, 2531 mg/kg, LD50

Guinea pig, oral, 1000 mg/kg, LD0

Guinea pig, oral, 2000 mg/kg, LD50

Neopentyl glycol

Rat, oral, 3200 mg/kg, LDLo

Hexylene glycol

Human, inhl, 50 ppm, (15 min), TXL0; eye effects

Rat, oral, 3696 mg/kg, LD50

Mouse, oral, 3860 mg/kg, LD50

Mouse, oral, 2 ml/kg, hypnosis

Mouse, ip, 1299 mg/kg, LD50

Human, inhl, 100 ppm, (15 min), nasal irritation; respiratory discomfort

Human, inhl, 1000 ppm, (15 min), eye, nose and throat irritation; respiratory discomfort

Rabbit, dermal, 1840 mg/kg, (24 hr), mild edema, erythema

Rabbit, dermal, 13.3 mg/kg, (-), LD50

Mouse, oral, (gt)2.0 ml, irritation of lungs and large intestine

Trimethylpentanediol

Rat, oral, 2000 mg/kg, LDLo

Rat, ip, 800 mg/kg, LDLo

Mouse, oral, 2200 mg/kg, LDLo

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SILICON AND ITS COMPOUNDS

I. Description of Chemicals

There are 5 major industrially important groups within the class of chemicals "silicon and its compounds." They are:

silicates
silanes
silicones or siloxanes
silicon
metallurgical silicons and silicides

A. Silicates

The major silicates used in industry are grouped as soluble silicates or insoluble silicates; the former being more important. The soluble silicates of greatest importance are:

sodium tetrasilicate (water glass)
sodium metasilicate
sodium orthosilicate
sodium sesquisilicate
potassium silicate

The major insoluble silicates used in industry are:

aluminum silicate
calcium silicate
copper silicate
lead silicate
magnesium silicate
zinc silicate

B. Silanes

The silanes have the general formula $Si_n H (an+2)$ from which many other silane compounds are derived. Derivatives have been produced by replacing one or more of the hydrogen atoms with an inorganic or organic group. Examples of these groups are halogens, oxygen, nitrogen, metals, and various organic compounds. Some silanes of major industrial importance are:

organochlorosilanes
methylchlorosilanes
trichlorosilane
tetrachlorosilane
phenyl chlorosilanes
phenyl ethoxysilanes
methyl ethoxysilanes

C. Silicones or Siloxanes

The silicones refer to any organosilicon oxide polymer in which the structural unit is $-R_2$ Si- ; R being any organic radical. The silicone compounds are classified as:

silicone fluids
silicone elastomers
silicone resins

D. Silicon

Silicon, which is never found in nature but as silica or silicate, makes up 25 percent of the earth's crust. It is the 14th element of the periodic series with an atomic weight of 28.083.

E. Metallurgical Silicon and Silicides

Silicon forms bonds with several metals, of which many have important use in industry. The most important commercial products in this group are ferrosilicon, silvery iron, boron silicides, calcium silicide, chromium silicides, copper silicon, magnesium silicides, rare earth silicides, manganese silicides, titanium silicides, vanadium silicides, and silicon metal. This group of silicides is also referred to as silicon alloys.

II. Production

A. Silicates

There are 14 producers of the sodium silicate compounds and 4 producers of potassium silicate. In 1973, 723,000 short tons of water glass and sodium sesquisilicate were produced, the great majority of which was water glass. In 1970, 225,000 short tons of sodium metasilicate and 36,000 short tons of sodium orthosilicate were produced. No production figures are available for potassium silicate.

There are several producers for each of the insoluble silicates; 14 for aluminum, 10 for calcium, 6 for copper, 7 for lead, 8 for magnesium, and 7 for zinc. Production figures are not available for these compounds.

B. Silanes

Production data has not been found on the silanes, of which there are 6 producers.

C. Silicones or Siloxanes

There are 4 major producers of silicones; over 150,000,000 pounds were produced in 1974. The three major groups are derived in different ways. The silicon fluids are produced by hydrolysis of methylchlorosilanes and then condensed to form polysiloxane. Silicon elastomers are derived from

ring opening of cyclic siloxanes followed by polymerization of the siloxanes. Silicon resins are prepared by hydrolysis of a blend of organochlorosilanes in a solvent.

D. Silicon

There are 8 major producers of silicon, making various grades of the product ranging from pure silicon to a grade containing 21-55 percent silicon. In 1966 640,780 tons of silicon was produced, half of which was the 21-55 percent silicon grade. Other important grades were 100 percent silicon, 71-80 percent silicon, and 40-50 percent silicon.

E. Metallurgical Silicon and Silicides

In 1967, about 2 million short tons of silicon alloys were produced. The number of producers could not be identified, but it appears only a handful of companies are involved in the production of each specific alloy. For example, there are 3 producers of ferrosilicon, 3 producers of silicon aluminum alloy, and 1 producer of silicon manganese alloy. Production figures are available for only a few of the alloys. In 1970, 709,300 short tons of ferrosilicon and 196,400 short tons of silvery iron were produced. About 75,000 tons of silicon metal were produced in 1967. Ferrosilicon and silvery iron are by far the most important silicon alloys, comprising almost one-half of the total production.

III. Uses

A. Silicates

The sodium silicates are used as an alkali in industry. They are components in detergents, used in adhesives, in silica gels, for water, paper, and ore treatment, and in pigments. The potassium silicates are used in chemical coatings, as fire-resistant adhesives, and in paints resistant to high temperature.

The insoluble silicates have many uses: the aluminum silicates are used as catalysts, to form coatings on pigments, and for decolorizing mineral oils; magnesium silicate has use in pharmaceutical compounds, antioxidants, and stabilizers; calcium silicate is used in soils, fertilizers, and pharmaceutical compounds; copper silicate is used in pigments, catalysts, and insecticides; lead silicate is used to protect rubber compounds and films; and zinc silicate is used in spraying compounds.

B. Silanes

The parent silane compounds are reported to have little application in industry; however, many of the derivates have wide use. Many are used in chemical synthesis. For example, many of the organochlorosilane compounds are used to produce silicone fluids and silicone resins. Trichlorosilane and tetrachlorosilane are used in the manufacture of transistors.

C. Silicones or Siloxanes

In 1973, 130,600,000 million pounds of silicones were consumed. Of this amount, 70 million pounds was used as silicone fluids, 35 million pounds for silicone elastomers, 12.6 million pounds for silicone resins, and 13 million pounds for silicone surfactants. Silicone fluids are used in the production of waxes, polishes, spray lubricants, and cosmetics. They are also used by the textile, electronic, rubber, automotive, and paper industries. Silicone elastomers are used in protective coatings for electrical and electronic components, in aircraft, missiles, and automobiles because of their high temperature resistance, in household seals and cements, as insulation material, and in plastic-type materials for biomedical application. Silicone resins are used in electrical insulation, protective coatings, as a brick-treating agent, and in temperature resistant paints. Silicone surfactants are used in the production of flexible and rigid polyurethane foams.

D. Silicon

Pure silicon has wide use in semiconductor manufacture. The various grades of silicon are also used in the manufacture of silicon alloys such as ferrosilicon, and in the production of silanes and silicones.

E. Metallurgical Silicon and Silicides

These compounds are widely used in the production of iron and steel, specifically for alloying, deoxidizing, and reducing other alloying agents. They are also used by the non-ferrous metal industry in the production of various alloys.

IV. Toxicity

A. Toxicity Data

Silicates

sodium tetrasilicate: rat-oral, LD50 1280 mg/kg
sodium metasilicate: rat-oral, LD50 1600 mg/kg
sodium orthosilicate: rat-oral, LD50 1300 mg/kg

Silanes

silane: mouse-inhalation, LCLO 9600 ppm/4 hours
methyl trichlorosilane: rat-oral, LDLO 1000 mg/kg
rat-inhalation, LCLO 450 ppm/4 hours
dimethyl dichlorosilane: rat-oral, LDLO 1000 mg/kg
rat-inhalation, LCLO 930 ppm/4 hours
trichlorosilane: rat-oral, LD50 1030 mg/kg
rat-inhalation, LCLO 1000 ppm/4 hours
tetrachlorosilane: rat-inhalation, LC50 8000 ppm/4 hours
dimethyl diethoxysilane: rat-oral, LDLO 3000 mg/kg
phenyl triethoxysilane: rat-oral, LD50 2830 mg/kg
rabbit-skin, LD50 3180 mg/kg
trichlorophenyl silane: rat-oral, LD50 2390 mg/kg
rabbit-skin, LD50 890 mg/kg

B. Toxicity Information

1. Silicates

The sodium silicates are irritating and caustic to the skin and mucous membranes. They can cause blisters and ulcers of the skin. Ingestion results in vomiting and diarrhea. The sodium sesquisilicate, anhydrous form, is reported to be the most toxic of these compounds. It may cause death or permanent injury after a short dermal exposure or by ingestion. The toxicity of these compounds by other routes is not known. Given by the oral route to rats, the LD50 of the sodium silicates, excluding sesquisilicate, range from 1280-1600 mg/kg.

Little information is available on the toxicity of the insoluble silicates. Calcium silicate is slightly toxic by inhalation or ingestion; any effects have been found to be reversible after exposure ends. Lead silicate has been incorporated in the NIOSH inorganic lead criteria document which recommended a TLV of 0.15 mg Pb/cu m.

2. Silanes

The silanes are reported to be highly toxic by inhalation, ingestion, or skin contact, following an acute exposure. Any of the chlorosilanes can emit a highly irritating, asphyxiating vapor. HCl is liberated upon hydrolysis.

3. Silicones or Siloxanes

The silicone fluids and silicone elastomers are inert, and reported to be harmless. Even when implanted into the body they produce no adverse reaction. The silicone fluids have produced some toxic effects. Inhalation of the vapor at high concentrations can cause a fatal narcosis. These fluids can irritate the ocular mucosa to a slight extent, causing redness, pain, and lachrymation. The low molecular weight silicone fluids are generally the most toxic in this group.

4. Silicon

Silicon is an inert material, and generally does not produce toxic effects. High concentrations of the dust can produce pulmonary irritation.

5. Metallurgical Silicon and Silicides

The toxicity of these compounds is generally unknown. Ferrosilicon can decompose under moist conditions, resulting in impurities liberating poisonous gases such as phosphine and arsine. On contact with acid it can emit toxic fumes. The individual metals will influence the toxicity of each of the specific silicides, therefore the hazards are variable.

V. Standards

The following are the only standards relevant to "Silicon and its Compounds:"

Silane - ACGIH 1976 - 0.5 ppm (0.7 mg/cu m)
lead silicate - NIOSH criteria document (inorganic lead)- 0.15 mg Pb/cu m

VI. Environmental Data

No information is available on the environmental concentrations of the various silicon compounds found in the workplace.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Sodium metasilicate	750,000
Sodium orthosilicate	less than 5,000
Aluminum silicate	200,000
Sesquisilicate	less than 1,000
Sodium silicate	3,449,000
Silicones	2,890,000
Dimethyl silicone	200,000
Trichlorophenyl silane	less than 1,000
Magnesium silicate	1,000,000
Dimethyl dichlorosilane	less than 1,000
Ferrosilicon	30,000
Silicon	100,000
Silicone oil	1,000,000

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ACETATES

I. Description

The following nonfiber acetates were found to be industrially important; however, cellulose acetate and triacetate are commercially used for the production of household fabrics.

Vinyl acetate -	1210.7 million pounds (1976)
Ethyl acetate -	212.0 million pounds (1976)
n-Butyl acetate -	77.2 million pounds (1974)
Isopropyl acetate -	40.0 million pounds (1976)
Propyl acetate -	32.4 million pounds (1976)
Sodium acetate -	16.5 million pounds (1968)
Methyl acetate -	8.8 million pounds (1966)
Amyl acetate -	7.6 million pounds (1964)

Benzyl acetate
Ethylphenyl acetate
Methylphenyl acetate
Sodium phenoxy acetate
Ethyl acetoacetate
Cedryl acetate
Alpha-terpinyl acetate
Geranyl acetate
Alpha-methylbenzyl acetate
Linalye acetate
Anisyl acetate
2-Phenethyl phenylacetate
Isobutyl acetate
2-Methoxyethyl acetate
Isobutyl phenyl acetate
sec-Butyl acetate
Isoamyl acetate
Isobornyl acetate
Nopyl acetate
Benzyl phenyl acetate
Cirtonellyl acetate
Betivenyl acetate
Hexyl acetate
Heptyl acetate
2-Ethylhexyl acetate

The early acetates were almost completely acetylated and were not soluble in volatile solvents. The development of the soluble acetates was done by removing some acetyl radicals by acid hydrolysis. Acetate and triacetate flakes are the materials from which the fibers are produced by extrusion, while nonfiber acetates are white amorphous solids which can be produced in granular, flake, or powder form by varying the process preparation. The commercial products (acetate and triacetate) do not have sharp melting points. The solubility, the viscosity, and the degree of hygroscopicity of

of various acetates are affected by the acetyl value. Acetates can be hydrolyzed in the presence of aqueous alkalies. Strong acids and alkalies decompose cellulose acetate.

II. Production:

In the preparation of acetate fibers from acetate flakes, a relatively concentrated solution of the polymer is extruded through a small orifice. Two methods are commonly used to prepare cellulose acetate for the fibers industry. In one method, the acetylation with acetic anhydride is carried out in the presence of glacial acetic acid, and in the other method, which is known as the solvent process, glacial acetic acid is replaced by methylene chloride.

In 1975, 605.3 million pounds of acetate fibers were produced in the United States in which about 562.3 million pounds (93%) were based on cellulose acetate and remaining 43.0 million pounds (7%) were cellulose triacetate. From 1960 to 1975, total production of cellulose acetate and triacetate fibers grew at an average annual rate of 2.7% which was equivalent to an average annual increase of 11.3 million pounds. However, between 1970 and 1975, their production declined at an average annual rate of 2.4%, which was equivalent to an average annual loss of 16.6 million pounds. In 1975, world production of cellulose acetate and triacetate fibers was 1.3 billion pounds. The largest acetate fiber producing countries are the U.S.A., the U.S.S.R., and the United Kingdom.

In May, 1976, there were 4 major companies in the U.S.A. that produced acetate fibers at 7 plant locations. Total production capacity was 733 million pounds (Celanese Corporation - 373 million pounds, Tennessee Eastman Company - 265 million pounds, E.I. duPont de Nemours and Company, Inc. - 50 million pounds, and Avtex Fibers, Inc. - 45 million pounds). Production of acetate fiber is decreasing because of its poor abrasion resistance and wet stability compared with other fibers and yarns.

In 1981, consumption of all acetate fibers is expected to be 488 million pounds which is a decrease of 8 million pounds from 1975, consumption and an average annual rate of decline of 0.3%. Production and consumption figures for nonfiber acetates are given in Section I.

III. Uses:

Because of the uniform quality, color versatility, drape, and other desirable aesthetic properties of the acetate fibers, their major applications are in women's apparel and home-furnishing fabrics. Their most important nontextile use is as a filter for cigarettes. They are also used in the preparation of electrical insulators, liquid filters, reinforced paper and plastic tapes, colored electric-wire markers, nonwoven fabrics, flocks, tassels, toys, and felts. Nonfiber acetates are mainly used as flabors and in perfumes. They are also used as solvents for coatings, plastics, synthetic rubbers, vinyl resins, and inks.

IV. Toxicity Information:

A. Target organs: The mucous membranes of the eyes, nose, and of the upper and lower respiratory passages.

B. LD50 Values:

Ethyl acetoacetate:

Rat-oral - 3.98 g/kg.

Ethyl acetate:

Rat - subcut. - 5.00 g/kg
inhalation - 1.60 g/kg
Mouse - ip - 0.71 g/kg
Cat - subcut. - 3.00 g/kg
Rabbit - Oral - 4.93 g/kg.
Guinea Pig - Subcut - 3.00 g/kg.

N-Butyl Acetate:

Mouse - ip - 1.23 g/kg.

2-Methoxyethyl Acetate

Rats - oral - 3.93 g/kg.
Guinea Pig - oral - 1.25 g/kg.

Amyl Acetate:

Rabbit - oral - 7.40 g/kg.

Methyl Acetate:

Rabbit - oral - 3.70 g/kg.

Isopropyl Acetate:

Rat - oral - 3.00 g/kg.

Isobutyl Acetate:

Rabbit - oral - 4.76 g/kg.

Propyl Acetate:

Rabbit - oral - 6.63 g/kg.

Sodium Acetate:

Rat - oral - 3.53 g/kg
Mouse - subcut - 8.00 g/kg.
Mouse - iv - 0.321 g/kg.

Vinyl Acetate:

Rat - oral - 2.92 g/kg.
Rat - ip - 0.50 g/kg. (LD LO)
Rabbit - skin - 2.32 g/kg.

2-Ethylhexyl Acetate:

Rat - oral - 3.00 g/kg.

C. Acute/subchronic effects:

Irritation of the mucous membrances of the eyes, gums, nose, and respiratory passage has been observed. Acetates also mildly narcotic to laboratory animals. On repeated or prolonged exposures, they caused conjunctival irritation and corneal clouding. They also produced dermatitis. High concentrations of acetates produce a narcotic effect and cause congestion of the liver and kidneys.

D. Long-term effects:

In chronic poisoning, nonfiber acetates produced anemia, leucoytosis, cloudy swelling, and fatty degeneration of the viscera in laboratory animals. Human exposure to isoamyl acetate at a high concentration resulted in irritation, dyspnea, increased pulse and fatigue. Occular and nervous disturbances in workers exposed to methyl acetate vapor for a long period have been reported. Inflammation of the eyes, nervous irritation, and tightness of the chest have also been observed. Workers exposed to concentrations exceeding the TLV should be under medical observation. No cases of irritation or systemic injury have been reported from industrial exposures at or below the TLV. It has been reported that cellulose acetate is nontoxic.

E. Carcinogenicity, Mutagenicity, Teratogenicity, and Other Effects on Reproduction:

No reports which address the subject of possible carcinogenic, mutagenic, teratogenic, or other effects on reproduction properties of acetates were found. Research efforts should be initiated in these areas to answer these important questions.

F. Epidemiologic Studies:

Epidemiologic studies of acetates have not been found in the literature. Such studies are needed to provide information on occupational exposures to acetates and to determine the relationship between airborne concentrations and observed effects on humans.

V. Standards:

The recommended ACGIH Threshold Limit Values (1976) of the following acetates are:

Ethyl acetate -	450 ppm or about 1400 mg/cum
n-Butyl acetate -	150 ppm or about 710 mg/cum
sec-Butyl acetate -	200 ppm or about 950 mg/cum
tert. Butyl acetate -	200 ppm or about 950 mg/cum
Methyl acetate -	200 ppm or about 610 mg/cum
Isobutyl acetate -	150 ppm or about 700 mg/cum
n-Amyl acetate -	100 ppm or about 525 mg/cum
sec-Amyl acetate -	125 ppm or about 650 mg/cum
Isoamyl acetate -	100 ppm or about 525 mg/cum
Isopropyl acetate -	250 ppm or about 950 mg/cum
n-propyl acetate -	200 ppm or about 840 mg/cum
sec-hexyl acetate -	50 ppm or about 300 mg/cum
2-Ethyoxyethyl acetate (skin) -	100 ppm or about 540 mg/cum
2-Methoxyethyl acetate (skin) -	25 ppm or about 120 mg/cum

VI. Environmental Data:

Mild eye, nose, and throat irritation was observed in workers exposed to ethyl acetate at a concentration of 400 ppm. Only eye irritation was reported in workers exposed to isopropyl acetate at 200 ppm. Humans exposed to isopropyl acetate at 200 ppm. Humans exposed to isoamyl acetate for a full half hour at 1000 ppm experienced irritation, dyspnea, increased pulse rate, and fatigue. Ocular and nervous distrubances in workers exposed to methyl-acetate vapor were reported. However, no cases of irritation or systemic injury have been reported from industrial exposures at or below the TLV of methyl acetate and 2-methoxyethyl acetate. Workers exposed to methyl acetate at concentrations exceeding 100 ppm should be kept under medical observation.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey:

Ethyl acetate -	2.659,000
n-Butyl acetate -	1,894,000
sec-Butyl acetate -	1,000,000
Methyl acetate -	1,433,000
Isobutyl acetate -	1,292,000

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HEAVY METAL GREASES AND SOAPS

I. Description

Heavy metal greases are prepared by heating mineral oil or synthetic organic liquids with metallic soaps. The percentages of metallic soaps in heavy metal greases varies from less than 1 percent in light spindle oil to up to 50 percent in heavy bodied grease. Calcium and sodium soaps account for 70 percent of the metallic soaps used in making these heavy metal greases. Petroleum oil is used in over 99 percent of the greases.

Heavy metal soaps are salts of heavy metals with long chain organic acids and are used in many industrial processes.

Based on production, the following metal greases and soaps are of industrial importance.

Greases

Aluminum, calcium, lithium, sodium and barium

Soaps

Stearates

Calcium, zinc, aluminum distearate, aluminum stearate, magnesium, lead and lithium

Naphthenates

Lead, cobalt, copper, calcium, manganese, zinc, and iron

2-ethyl-hexanoates

Cobalt, calcium, zirconium, zinc, lead and manganese

Tallates

Cobalt, lead, manganese, and calcium

Oleates

Resinates

Cobalt and calcium

Linoleates

Cobalt and calcium

II. Production

The total production of metal soaps in 1975 was reported by The National Lubricating Grease Institute (Table 1). An earlier report showed the relative abundance of various heavy metal soaps and the total annual productions for 1972. These are summarized in Table 2.

The major processes used in the production of metallic soaps are as follows:

where: R-alkyl radical, M-bivalent metal

1. Precipitation Process - Classical method

$$R\text{-}COOH + NaOH \rightleftharpoons RCOONa + H_2O$$
$$2R\text{-}COONa + MSO_4 \rightleftharpoons M(RCOO)_2 + Na_2SO_4$$

2. Fusion Process

$$M(OH)_2 + 2R\ COOH \rightleftharpoons (RCOO)_2M + H_2O$$

This process requires raw materials of high purity, heating and mechanical agitation.

3. Direct Solution of Metals - requires dissolving the desired metal directly into the heated organic acids.

III. Use

Greases are used as lubricants for machines and automobiles. Lithium greases are estimated to be more than 40 percent of the total greases used in the automotive industry in 1965, which amounted to 250 million pounds.

Heavy metal soaps are generally used as paint driers. Other more specialized uses are as follows:

Stearates: mold lubricants for rubber and plastics, water repellants, anticaking agents, and cosmetics and pharmaceuticals.

Naphthenates: lead salt constituted 55 percent (11.6 million pounds) of the total production in 1973. It was projected to be reduced to 5-6 million pounds by 1976.

2-ethyl-hexanoates: Al salts are used in gel paints. Barium and cadmium salts are used as heat stablizers for polyvinyl chloride.

Oleates: fungicides, lubricants, and waterproofing agents.

Table 1

NATIONAL LUBRICATING GREASE INSTITUTE

SUMMARY OF PRODUCTION REPORTED - UNITED STATES
FOR THE YEARS 1975

LUBRICATING GREASES	Thousands of Pounds Produced	Percentage of Total Lubricating Grease Production
Aluminum Soap		
Conventional (Dropping point below 350 degrees F)		
All companies	4,309	0.99
Complex (Dropping point above 350 degrees F)		
All companies	15,008	3.45
Total Aluminum Soap		
All companies	19,317	4.44
Calcium Soap		
Hydrated (Conventional)		
All companies	47,352	10.90
Anhydrous (Dropping point below 350 degrees F)		
All companies	16,632	3.83
Total Hydrated and Anhydrous		
All companies	63, 984	14.73
Complex (Dropping point above 350 degrees F)		
All companies	26,053	5.99
Total Calcium Saop		
All companies	90,037	20.72
Lithium Soap		
All companies	244,417	56.24
Sodium Soap		
All companies	24,971	5.75
Other Soap		
All companies	7,950	1.83
Non-Soap (Organic and Inorganic Thickeners)		
All companies	47,902	11.02
Total Lubricating Grease		
All companies	434,594	100.00

Table 1 (cont.)

	Thousands of Pounds Produced	Percentage of Total Lubricating Grease Production
FLUID GEAR LUBRICANTS		
E. P. Type		
All companies	375,242	
Straight Mineral Type		
All companies	73,678	
Total Fluid Gear Lubricants		
All companies	448,920	

Table 2

THE PRODUCTION OF SPECIFIC HEAVY METAL SOAPS
(In thousands of pounds)
(1963)

Heavy Metal \ Acid	Stearates	Naphthenate	2-ethylhexanoate	Tallate	Oleate	Resinate	Linoleate	Palmitate
Aluminum	di- 3693 -,others 1278							
Barium								
Calcium	10,836	1,364	687	401		-[1]	-[1]	
Copper		1,834						
Cobalt		2,670	453	2,154		-[1]	-[1]	
Iron		244						
Lead	646	9,308	223	3,554				
Lithium	279							
Magnesium	1,235							
Manganese		1,247	38	886				
Sodium								
Zinc	8,567	777	179					
Zirconium								
Others	4,351	283	1,804	588				
Total in Millions of Pounds								
(1972)	70.12	20.53	18.72	9.79[2]	1.29	.35	.27	
(1973)	75.75	20.17	11.39	7.46	1.01	.35 (1968)	.27 (1969)	.1

[1] Amount not given

[2] 1971 data

Linoleates and Resinates: printing ink

Palmitates: water proofing, pigment suspending, and rubber and plastic compounding.

IV. Toxicity

Heavy metal greases are rated as moderate in toxicity. Lead soaps are not absorbed through the skin. Their absorption is limited to inhalation and ingestion. Toxicity is relatively low.

V. Standards

No standards have been promulgated for heavy metal greases and soaps.

VI. Potential Exposure Estimates from the National Occupational Hazard Survey

Lithium grease	1,585,000
Metallic soaps, unclassified	500,000
Calcium soaps, unclassified	1,580,000
Lead soaps, unclassified	1,200,000
Potassium soaps, unclassified	2,000,000
Aluminum distearate	less than 5,000
Lead stearates	30,000
Aluminum stearate	1,647,000
Lithium stearate	60,000
Lead Naphthenate	1,500,000
Cobalt Naphthenate	less than 5,000
Calcium Naphthenate	less than 5,000
Cobalt Tallate	less than 5,000
Oleates, unclassified	50,000
Palmitates, unclassified	250,000

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ALKALI EARTH METAL PETROLEUM SULFONATES

I. Description

This class of compounds includes natural and synthetic petroleum sulfonates produced by sulfonation of detergent alkylate bottoms or specially prepared alkylaryl hydrocarbon. They are classified under lubricant oil and grease additives, as well as driers and metallic soaps. Typical detergents are metallic salts of petroleum sulfonates, phosphonates, phenates, and alkyl substituted salicylates.

Driers and metallic soaps are a group of water insoluable compounds containing alkaline earth or heavy metals in combination with monobasic carboxylic acids of 7-22 carbon atoms, Lithium, an alkali metal, forms soaps which are slightly water soluble. These soaps are represented by the general formula (RCOO)xM where R is an aliphatic or alicyclic radical and M is a metal with a valence of X. Metallic soaps of long and continued usage are aluminum, barium, calcium, copper, cobalt, iron, lead, lithium, magnesium, manganese, zinc and zirconium. Of the alkali earth metals, the calcium sodium and barium salts are the most commercially important.

II. Production

A. Manufacturing: Driers and metallic soaps are prepared commercially by three general methods.

1) precipitation from aqueous solutions of metal salts and alkali soaps

2) fusion of metal oxides, hydroxides, or salts with organic acids or esters and

3) direct solution of finely divided metals in heated organic acids

Commercial driers and metallic soaps are manufactured as solids, pastes and liquids. The color of the alkaline earths, Pb and Li soaps is usually white, when powdered, or light-colored when liquids in solution.

B. Production: Production figures were found for 1970 for the following cyclic petroleum sulfonates -- barium salts 16.9 million pounds, sodium salts 58.4 million pounds and "other" (include salts of oil soluble petroleum sulfonates) 137.6 million pounds. Increased production of sodium salts was predicted for 1971. The estimated growth rate of soap and other detergents (including soap, synthetic organic detergents, inorganic alkaline detergents, surface-active preparations

for use as wetting agents, emulsifiers and penetrants, sulfonated oils and fats and related compounds and crude and refined glycerin) was 5.6% between 1960 and 1971. There is evidence indicating that the volume of retail sales of soaps and detergents is diminishing under economic pressures. Inflation, on the other hand, has had the opposite effect on shipment values by the producing industry, which is predicted to reach $5 billion in 1976 and about 10% above the estimated 1975 figure of $4.5 billion. Synthetic organic detergents for household use continue to be the major product of the industry, comprising nearly 62% of the total shipment value. Assuming continued annual growth at the rate of 7%, the value of shipments of soap and other detergents by the industry is expected to reach $7 billion by 1985.

Cities Service Co., Inc., E. I. duPont de Nemours and Co., Inc., Henkel Inc., Mallinekrodt, Inc., Mobay Chemical Corporation and A. E. Staley Manufacturing Co. are producers of alkyl sulfonates. The North-Central, East and Middle-Atlantic states are the major producing areas of soaps and detergents.

III Uses

Synthetic detergents are used in domestic and industrial cleaning products as well as in leather manufacture (tanning, softening, soloring), textiles (scouring, fibre conditioning, finishing), paper and pulp (preparation and finishing), mining (ore-flotation), the chemical industry (production and processing of plastics), dyeing and coloring, oil, the engineering industry, building and civil engineering, the pharmaceutical industry and cosmetics, agriculture and the food industry, photography and fire fighting as a consequence of their great versatility.

Driers are used in paint, varnish, printing ink and linoleum industries. Metallic soaps of the alkali and alkaline earth metals have steep solubility curves. When heated with mineral oil and certain solar organic liquids, an apparent solution results which when cooled sets to a gel. These gels are the basis of many greases and special lubricants. Calcium and sodium soaps account for approximately 70% of metallic soaps used in grease making.

IV Toxicity Information

A. Target Organs: respiratory trait

B. LD50 value:

Barium sulfonates - Rat - Oral - 3000 mg/kg

C. Acute/Subchronic effects: Injuries occuring during the production or through the use of detergents have been few. They are usually limited

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to persons having an allergy either to the product or to one of its compounds. Diseases of the respiratory tract may occur if dust control in the working environment is not provided. Skin irritations are largely allergic reactions. When ingested, the soaps may be hydrolized to metal chlorides and free acids. Barium soaps have been considered as possible suspects in plastics used for food wrapping.

D. Long term effects: Hazards are usually associated with the toxicity of the alkali metals present, the solvents contained therewith and their activity as oxidation cayalysts. The concentrated compounds of metal alkyl sulfonates are only slightly toxic orally and act as slight irritant to the skin and more severely irritating to the eyes. No long term effects of any of these compounds have been found.

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction: No reports addressing this subject were found.

F. Epidemiologic studies: None were found.

V Standards

There are currently no standards set for any of the alkali earth metal petroleum sulfonates.

VI Environmental Data

It is recommended that inhalation of dust be avoided since respiratory tract irritation can result.

VII Potential Exposure Estimates from National Occupational Hazard Survey

Calcium (salts)	2,800,000
Barium (salts)	2,800,000

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ALUMINUM AND ITS COMPOUNDS

I. Description

A review of production and consumption figures has shown the following are compounds to be industrially important:

Aluminum oxide
Aluminum
Aluminum chloride (anhydrous)
Aluminum chloride (hydrous)
Aluminum sulfate
Aluminum fluoride
Sodium aluminate

Alkylaluminum compounds:
Diethyl aluminum hydride
Diisobutyl aluminum chloride
Diisobutyl aluminum ethoxide
Tri-n-hexyl aluminum
Trimethyl aluminum
Tri-n-octyl aluminum
Tri-n-propyl aluminum
Tri-ethyl aluminum
Triisobutyl aluminum
Tri-n-dodecyl aluminum
Tri-n-hexyldecyl aluminum
Triisohexyl aluminum

II. Production

Aluminum is produced by the electrolysis of bauxite ($Al_2O_3 \cdot 2H_2O$) in a bath of molten cryolite (Hall process). Nearly 40% of the total primary aluminum is made via hydropower applications. Secondary aluminum is made from worn or discarded products and in 1975, approximately 85 thousand short tons of aluminum was recovered by this method and in 1976, it was estimated to be 100 thousand short tons.

In 1973, 4,530 thousand short tons of primary aluminum was produced in the United States and a decrease was projected for the future. In 1974, 37 thousand short tons of aluminum chloride (anhydrous) was produced with a projected 130 thousand short tons for 1976. In 1974, 6,950 thousand short tons of aluminum oxide (alumina) was produced. Production of aluminum chloride (hydrous) in 1971 was 5.6 thousand short tons with a downward trend indicated from the data seen. Total aluminum sulfate production for 1974 was 1,519 thousand short tons, and in 1973, 140 thousand short tons of aluminum fluoride was produced. Allied Chemical Co., Aluminum Company of America, Kaiser Aluminum and Chemical Corporation and Reynolds Metals Company are the principal manufacturers of aluminum and its compounds. The alkylaluminums are produced mostly by Texas Alkyls and the Ethyl Corporation.

III. Uses

The major use of aluminum and its compounds is in the building industry. Aluminum also is used in consumer durables and in containers and packaging. The automobile industry is also an important and a growing consumer of aluminum. The natural forms of aluminum minerals are utilized in water and sugar purification and in the brewing and paper industries. Several forms of aluminum oxide are used as abrasives and refractories and as catalysts and catalyst carriers. Activated alumina is used as an adsorbent and hydrated aluminas are used as pigments and fillers.

Aluminum has quite a widespread and diversified market and has now expanded to more than 3,500 uses compared with 1,500 before World War II. It is found in the composition of several alloys, such as "Duralumin" and "Magnalium" with aluminum comprising 90-95 per cent, and magnesium 5-10 per cent. The aluminum salts are used as mordants in the textile industry; aluminum stearate is used as a stabilizer in various oils and greases.

Alkylaluminums are growing in importance as catalysts for production of low-pressure polyethylene. Two-thirds of the aluminum sulfate produced is used in the paper industry and is therefore considered a no-growth chemical because of capacity limitations in paper mills. These mills are finding ways of more efficient utilization; capacity is adequate for present and projected demand.

IV. Toxicity information

A. Target organs: Aluminum sulfate readily hydrolyzes to form some sulfuric acid thereby acting as a tissue irritant, especially to the lungs.

B. LD50 and LDLO Values:

Aluminum chloride (anhydrous)	Rat	Oral	3700 mg/kg	
	Mouse	Oral	3805 mg/kg	
Aluminum sulfate	Mouse	IP	270 mg/kg	
Aluminum fluoride	Guinea pig	Oral	600 mg/kg	LDLO
		Subcutaneous		3000 mg/
	Frog	Subcutaneous	1680 mg/kg	LDLO

C. Acute/Subchronic effects:

The insoluble forms of aluminum compounds are without noticeable toxicity by any route as long as the administration is not associated with substances that are tissue irritants. Inhalation of powdered aluminum produces no injurious response.

On the other hand, the more soluble forms of aluminum have a measurable amount of toxicity. A single, subcutaneously injected dose of 100 mg of Al/kg as $Al_2(SO_4)_3$ is acutely toxic and even fatal to rabbits; the

acute ip toxicity is even greater. Aluminum salts in concentrations of 1 per cent or greater will precipitate in the blood stream causing emboli. The lethal oral doses of the acetate and chloride of aluminum in experimental animals appear to be between 5-15 g/kg for the acetate and 1-3 g/kg for the chloride.

The alkylaluminum compounds are extremely hazardous due to their reactivity and must be protected from air, moisture, and compounds containing active hydrogen. It has been shown that skin is easily burned by the undiluted compounds even when protected by cloth or polyethylene sheeting. Twenty per cent dilutions have been shown to be without reaction.

D. Long-term effects:

There have not been any occurences of chronic toxicity from aluminum or its salts for either man or animal as long as exposure was not found in conjunction with other tissue irritants. Clinical findings have shown that patients receiving 15 g/day of $Al(OH)_3$ for 6 months or longer showed no harmful effects.

Sensitivity to aluminum dust is rare and there is no evidence of pulmonary or bronchial injury as a result of aluminum dust exposure. Animals exposed to the dust were found to exhibit considerable proliferation of fibroblasts, monocytes, foreign body giant cells and moderate interstitial substance. Others have found a number of cases of lung disease occurring in the production of alumina abrasives, and is primarily an interstitial lung fibrosis, non-nodular in type.

A lethal disease associated with corundum production involving inhalation of aluminum or aluminum oxide in combination with other substances has been observed. Symptoms were dyspnea, sudden attacks of extreme shortness of breath, substernal discomfort, tightness in the chest, pleuritic chest pain, weakness and fatigue. Physical findings included tachypnea, cyanosis and respiratory distress in the advanced stages.

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction:

No reports regarding this subject area for aluminum and its compounds were found. Further efforts should be made in locating studies involving these important issues.

F. Epidemiology studies:

No epidemiological studies were found involving aluminum and its compounds. Efforts should be made in locating such studies.

V. Standards

No threshold limit for aluminum has been set in this country due to the lack of hygienic significance associated with aluminum exposures. A level of 15 mg/cu m as recommended by Elkins represents an upper limit of dustiness set for all innocuous dusts.

The ACGIH (1976) TLV for aluminum oxide is 10 mg/cu m

VI. Environmental data

Reports were found in relation to the pulmonary fibrosis in workers exposed to very fine aluminum powder. Symptoms included progressively worsening dyspnea, weight loss, tightness in the chest and cough. Avoidance of inhalation of dust is desirable.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Aluminum	600,000
Aluminum ammonium sulfate	30,000
Aluminum chloride	360,000
Aluminum hydroxide	60,000
Aluminum oxide	600,000
Aluminum paste	30,000
Aluminum phenolsulfonate	27,000
Aluminum potassium sulfate	300,000
Aluminum powder	75,000
Aluminum Silicate	210,000
Aluminum Stearate	1.6×10^6
Aluminum sulfate	120,000

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ORGANOPHOSPHATE COMPOUNDS

I. Description

This class of compounds has been defined to include all organophosphates except those used primarily as pesticides and fire-retardants. A review of production and consumption data has shown that two major groups, cyclic and acyclic phosphate esters, are industrially important.

Cyclic phosphate esters

Tricresyl phosphates	)-	56 million lbs.
Cresyl diphenyl phosphate	)-	11.1 million lbs.
Triphenyl phosphate	)	
2-ethylhexyl diphenyl phosphate	)	
Isodecyl diphenyl phosphate	)	
Dibutyl phenyl phosphate	)	
Trixylenal phosphate	)	
Triisopropyl phenyl phosphate	)	Others
Triaryl phosphates	)	27.7 million lbs.
Isopropyl phenyl diphenyl phosphate	)	
Diphenyl phosphate	)	
Trixylenyl phosphate	)	
t-butyl phenyl diphenyl phosphate	)	

Acyclic phosphate esters — 28.5 million pounds

Tri (2- chloroethyl) phosphate
Tri (2- chloropropyl) phosphate
Triethyl phosphate
Tri (2-butoxyethyl) phosphate
Trioctyle phosphate
Tributyl phosphate
Amyl acid phosphate
n-butyl acid phosphate
Isooctyl acid phosphate
Octyl acid phosphate
Mono-n-butyl acid phosphate
Diethyl chlorophosphate
Ethyl acid phosphate
Tridecyl acid phosphate
Dimethyl phosphate
Diethyl phosphate
Tris (2,3-dibromopropyl) phosphate
Tri (ethylhexcyl) phosphate
Triethyl ammonium phosphate
Triethanolamine phosphate

The majority of these materials are very high-boiling liquids, although some exist as low-melting solids. Their vapor pressures are quite low. The triphosphates are usually stable to hydrolysis. The mono or diesters are acidic and may hydrolyze readily.

II. Production

About 4% of the elemental phosphorus produced in the United States is used in the production of organic phosphorus compounds. The phosphate esters are usually prepared by adding phosphorus oxychloride or phosphorus trichloride slowly to the appropriate alcohol or phenol in a well-stirred, closed vessel.

In 1974, 123.3 million pounds of phosphate ester plasticizers were produced in the United States of which 28.5 million pounds were acyclic phosphates. The estimated growth rate of these products was 7.4% between 1963 and 1973. FMC, Stauffer, Monsanto, Sobin Chemicals, Inc., and Ciba-Geigy Corporation are the principal producers of phosphate ester plasticizers.

III. Uses

Organophosphate compounds are widely used as plasticizers, solvents for resins, waterproofing and fireproofing. They are also used as oil additives, flotation agents, stabilizers for surface coatings, cable impregnation and sheath, lacquers, lubricants, textile coatings and adhesives. More recently, they have been used as gasoline additives and combining agents for plastics.

In 1972, about 2 million pounds of cresyl diphenyl phosphate was used in gasoline, while its use as a vinyl plasticizer has increased substantially. The use of organophosphate compounds is increasing rapidly.

IV. Toxicity Information

A. Target organs: Central nervous system and gastrointestinal organs (oral).

B. LD50 Values:

Triisobutyl phosphate:

Rat - oral 3.2-6.4 g/kg
ip 0.8-1.6 g/kg

Tri-2-ethyl isohexyl phosphate

Rat - oral 25.0 g/kg
ip 6.4-12.8 g/kg

Tri-2-ethylhexcyl phosphate

Rat - oral 37.0 g/kg
ip 30.0 g/kg
Mouse - oral 12.8 g/kg
ip 3.2.-6.4 g/kg

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2-Ethylhixyl diphenyl phosphate:

Rat - oral 24 g/kg
Rabbit - skin 13 g/kg

Triphenyl phosphate:

Rat - oral 6.4 g/kg
Cat - subuct 0.1-0.2 g/kg
Chicken - oral 2.0 g/kg

Tri-o-cresyl phosphate:

Rat - oral, 3.0 - 10.0 g/kg
Cat - subcut 0.1 - 0.2 g/kg
Chicken - oral 0.1 - 0.2 g/kg

Tri-p-cresyl phosphate:

Rat - oral 12.8 g/kg
Cat - subcut 1.0 g/kg
Chicken - oral 2.0 g/kg

Cresyl diphenyl phosphate:

Rat - oral 6.4 - 12.8 g/kg
Mouse - oral 6.4 - 12.8 g/kg

C. Acute/subchronic effects:

Fatalities were quite rare and occurred in those who had taken larger quantities in a short period of time. Flaccid paralysis of the posterior extremeties and to a less degree of the anterior in cats and dogs was observed. Irritation of the skin and respiratory tract was also observed.

D. Long-term effects

A polyneuritis with flaccid paralysis of the distal muscles of the upper and lower extremeties was noticed. In the case of tri-o-cresyl phosphate toxicity, some serious gastrointestinal disturbance followed by paralysis of feet, legs, arms, and hands with muscular atrophy, sharp cramplike pains, numbness of the legs and feet, development of bilateral footdrop, and finally dysfunction in the motor system were observed. About 20-30% of the cases had permanent residual effects.

In general phosphate esters have been shown to produce 5 types of toxic effects. These are listed below with some of the compounds that produce each type of effect.

1. Organic damage to the CNS, resulting in flaccid or spastic paralysis

Trimethyl phosphate
Triphenyl phosphate
Tri-o-cresyl phosphate

2. Convulsive or CNS stimulant action, or, in some cases, an anesthetic action.

Tri (2-chloroethyl) phosphate
Tributyl phosphate
Triethyl phosphate

3. Relatively weak inhibition of true or pseudo-cholinesterase, with the latter predominating.

Triethyl phosphate
Triphenyl phosphate
Tri (2-chloroethyl) phosphate
Tri-o-cresyl phosphate

4. Irritation of skin and respiratory surfaces

Triallyl phosphate
Tributyl phosphate

5. No apparent major toxic effects.

2-Ethylhexyl diphenyl phosphate
p-cresyl diphenyl phosphate
Tri-p-cresyl phosphate

E. Carcinogenicity, Mutagenicity, Teratongenicity, and Other Effects on Reproduction

No reports which address the subject of possible carcinogenic, mutagenic, teratogenic, or other effects on reproduction properties of organophosphate compounds were found. Research efforts should be initiated in these areas to answer these important questions.

F. Epidemiologic Studies:

In 1930, an epidemic poisoning of tri-o-cresyl phosphate occurred in which about 10,000 - 15,000 people developed a neuromuscular disturbance characterized by flaccid paralysis, from which recovery was slow or with permanent disability. There have been 8 or 9 epidemics since that time, and one occurred in 1959 in Morrocco, involving several thousand persons.

V. Standards

The recommended TLV's of 0.1 mg/cu m (skin) tri-o-cresyl phosphate, 3 mg/cu m for triphenyl phosphate, and 5 mg/cu m for dibutyl and tributyl phosphates are 1976 ACGIH values.

VI. Environmental Data

With the concentrations of aryl phosphates ranged from about 0.2-3.4 mg/cu m, some occupational cases of polyneuritis and neurologic symptoms in workers from manufacturing various aryl phosphates were reported.

Avoidance of skin contact and inhalation of mist, dust, or vapor is desirable.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey:

Miscellaneous Organophasphate Compounds -	1,000,000
Tricresyl phosphate	2,800,000
Cresyl diphenyl phosphate	75.000
Triphenyl phosphate	75,000
Dibutyl Phenyl phosphate - less than	1,000
Tri(2-chloroethyl) phosphate - less than	1,000
Tri(2-chloropropyl) phosphate - less than	1,000
Tributyl phosphate	500,000
Triaryl phosphate	100,000
Triisopropyl phenyl phosphate - less than	1,000
Tri(ethylhexyl) phosphate - less than	1,000
Triethylammonium phosphate -	50,000
Trixylenal phosphate - less than	5,000

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ZINC AND ITS COMPOUNDS

I. Description

Zinc is used in industry for galvanizing, in the manufacture of brass and bronze, in zinc based alloys and in rolled zinc products. Zinc compounds have their applications in animal feed supplements, fungicides, pigments, and cosmetics. The most important zinc compounds are:

zinc sulfate
zinc chloride
zinc chromate
zinc borate
zinc stearate
di-n-butyl zinc
diethyl zinc
zinc dialkyl dithiophosphates
zinc dithiophosphates
zinc acetate

II. Production and Use

Zinc

Zinc concentrates for smelting into metal are obtained from zinc ores and as a by-product of lead ore mining. Tennessee, New York, Colorado, Idaho, New Jersey (zinc ores) and Missouri (lead ore by-product) accounted for about 70 percent of U.S. mine production during 1975. U.S. consumption exceeds the production of zinc so the U.S. is dependent upon imports to handle its industrial requirements. Total zinc production has shown a slight decrease since 1969. Outlined below are the 1973 figures for zinc production in thousands of short tons.

Primary slab from domestic ores	399
Primary slab from foreign ores	184
Secondary (new scrap)	294
Zinc content of chemicals produced directly from ores	130
TOTAL	1096

There are 7 primary slab zinc smelters in the United States.

1973 consumption of zinc. (thousands of short tons)

Consumption of Slab Zinc as Metal	
Zinc base alloys	611
Galvanizing	564
Brass and bronze	198
Rolled zinc	41
Other	10
Secondary Zinc converted directly to alloys	205
Zinc consumption for production of zinc compounds	
Zinc oxide	204
Zinc dust	56
Zinc chloride	17
Zinc sulfate	15
Lead zinc oxide, lithopone, and other	13
TOTAL	1932

Zinc Compounds

There were 232 thousand short tons of zinc oxide and 46.1 thousand short tons of zinc sulfate produced in 1974. Production figures were not available for other zinc compounds.

The major companies producing zinc and its compounds in this country are as follows:

Company and Location	Thousands of short tons of Zn (1976)
Amax Inc.	
Amax Zinc Co., Inc. Subsidiary	
Sauget, Illinois	84
Asarco Inc.	
Corpus Christi, Texas	n.a.
Stephensport, Kentucky	180
Englehard Minerals and Chemicals Corp.	
National Zinc Co., Subsidiary	
Bartlesville, Oklahoma	56
St. Joe Minerals Corp.	
Monaca, Pennsylvania	245
Gulf Resources and Chem. Corp.	
The Bunker Hill Co., Subsidiary	
Kellog, Idaho	104

Total production, including that of other companies not listed, amounted to 680 thousand short tons.

Zinc Compounds

The production of zinc chromate was 5.8 thousand short tons in 1974. In the same year the production of zinc sulfate was 21.1 thousand short tons. The production of zinc chloride was 28.0 thousand short tons in 1966. In 1971 the production of zinc oxide was 220.0 thousand short tons.

The processes used in producing zinc are electrolytic, horizontal retort smelter and vertical retort smelter.

III. Uses of Slab Zinc and Zinc Compounds

1. Zinc-based Alloys

There has been a rapid increase in the use of zinc in zinc-based alloys, practically all of which are used for die-casting. The automotive industry is the largest consumer of die-castings, and therefore, the consumption of slab zinc for zinc-based alloys is directly affected by the production of motor vehicles. Recent developments in thin wall die-casting, allow less zinc consumption in car parts. Consumption of slab zinc for zinc-based alloys reached a peak in 1965 (638,000 short tons) and dropped in 1967, 1970, 1974 and 1975 due to decreased automobile production. The amount of zinc used in the average automobile for die-casting is expected to drop from 50.5 pounds in 1975 to 44.5 pounds in 1976. Other markets for zinc-based die-castings include the home appliance, commercial machine and tool, plumbing and heating, and office equipment and business machine industries.

2. Galvanizing

Most galvanizing is done by immersion of an iron or steel product in molten zinc. The major industries using galvanized products are construction, agriculture, appliance manufacture, and automobile manufacture. The amount of slab zinc used for this process has steadily increased since 1959.

3. Brass and Bronze

Consumption of slab zinc in brass and bronze production has been variable during the last 25 years. In 1974, 148,800 short tons of secondary zinc were converted directly to brass and bronze.

4. Rolled Zinc

Rolled zinc is used in battery dry cells, as extruded cans for radio condensers and tube shields, weather stripping, photoengraving plates, and anodes to protect hot water tanks, boilers, ship hulls and pipelines. There has been a general decrease in the amount of slab zinc consumed for this purpose since 1969.

5. Zinc Compounds

Zinc compounds are used in animal feed supplements, fungicides, pigments, seed treatment agents, cosmetics, elastomers, and fireproofing textiles.

6. Other

Slab zinc is also employed in the production of wet batteries and for desilverizing lead and light metal alloys.

IV. Toxicity Information

Acute Exposure

Zinc is only toxic if ingested in large doses and causes serious damage to the buccal and gastrointestinal mucous membranes. Exposure to mists or fume of zinc may cause irritation of the respiratory or the gastrointestinal tract.

The soluble zinc salts are astringent, corrosive, and emetic. When ingested they may produce severe gastroenteric irritation, nausea, vomiting, diarrhea, and gastroenteric pain.

Zinc chloride can cause ulceration of skin. Zinc stearate has been implicated as a cause of pulmonary fibroses. Inhalation of zinc oxide fume results in a malaria-like illness called metal-fume fever.

Chronic Exposure

The symptoms resulting from chronic exposures are similar to those due to acute exposures. Prolonged exposure of the fine powder of zinc stearate has produced pneumonitis as well as fatal pneumonia in infants.

LD50 Values

Zinc Sulfate

rat - i.p., 0.04 g/kg
mouse - i.p., 0.029 g/kg
rabbit - subcut, (TDLO) 6.17 mg/kg/5 day continuous

Zinc Chloride

man - inhal, (TCLO) 4.8 g/cu m/30 minutes
rat - i.v., (LDLO) 0.03 g/kg
hamster - parenteral, (TDLO) 0.017 g/kg

Zinc Chromate

mouse - i.v., (LDLO) 0.03 g/kg

Zinc Dithiophosphate

rabbit - oral, (LDLC) 2.13 g/kg

Zinc Acetate

rabbit - oral, (LDLO) 0.98 of g/kg

Among the listed zinc compounds, zinc chloride and zinc sulfate are listed as suspected carcinogens. No information was available on the mutagenicity and teratogenicity of this group of compounds.

V. Standards

Three zinc compounds have occupational exposure standards established by the ACGIH (1976). These are:

zinc chloride fume	1 mg/cu m
zinc oxide fume	5 mg/cu m
zinc stearate	10 mg/cu m
zinc oxide dust	10 mg/cu m

VI. Environmental Data

None available

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Zinc	600,000
Zinc sulfate	1,000,000
Zinc chloride	1,600,000
Zinc chromate	500,000
Zinc acetate	1,000,000
Zinc dialkyl dithiophosphates	2,400,000
Zinc dithiophosphates	600,000

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PHTHALATES

I. Description

This class of compounds has been defined to include the esters of phthalic acid. More than 40 different phthalates have become important industrial commodities during the last several years. A review of production and consumption data has shown the following phthalates to be industrially important.

Phthalate anhydride esters

Di-2-ethylhexyl phthalate	389.7 million pounds
Di isodecyl phthalate	146.7 million pounds
Di butyl phthalate	35.5 million pounds
Di tridecyl phthalate	27.2 million pounds
Di ethyl phthalate	19.2 million pounds
n-Hexyl n-decyl phthalate	10.2 million pounds
Di methyl phthalate	10.0 million pounds
n-Octyl-n-decyl phthalate	568.5 million pounds
Di isooctyl phthalate	568.5 million pounds
Butyl octyl phthalate	568.5 million pounds
Di methoxyethyl phthalate	568.5 million pounds
Di isobutyl phthalate	568.5 million pounds
Di-n-octyl (DOP) phthalate	568.5 million pounds
Butyl benzyl phthalate	568.5 million pounds
Di nonyl phthalate	568.5 million pounds
Di undecyl phthalate	568.5 million pounds
Ethyl carbethoxymethyl phthalate	568.5 million pounds
Butyl carbobutoxyjethyl phthalate	568.5 million pounds

Isophthalic acid esters

Dioctyl isophthalate
Di-2-ethylhexyl isophthalate
(Di cyclohexyl phthalate)

In most cases phthalates are liquids with very high boiling points and very low vapor pressures. The low vapor pressure is important in contributing to their stability in plastics.

II. Production

When an alcohol is heated with phthalic anhydride, hydrogen phthalic esters are formed first, then a second mole of alcohol reacts to form diesters of phthalic acid, commonly known as phthalates.

In 1974, the United States produced 1,207 million pounds of total phthalate ester plasticizers with an average annual growth rate of 8.7% between 1963 and 1973. However, phthalate ester plasticizers production

was severely depressed in 1975. It was 25-26% less than in 1974.

About 90% of the total United States phthalate ester plasticizers is produced by six major producers with the following estimated market for 1976:

Monsanto	23-27%
Hatco	19-21%
U.S.S. Chemicals	14-16%
Exxon	14-16%
Tennessee Eastman Co.	8-9%
BAFS Wyandotte	7-8%

III. Uses

Phthalate esters are among the most important of industrial chemicals which are used as plasticizers for a variety of films in which they may be present as high as 30% or more by weight. They are used particularly with cellulose and vinyl resins and give the required properties of toughness and flexibility. As a plasticizer , diethylhexyl phthalate, commercially known as dioctyl phthalate, accounted for 44% and diisodecyl and diisooctyl phthalates each for about 16%. The longer-aliphatic-chain phthalates are primarily used as flexibilizing plasticizers for vinyl chloride plastics. The intermediate-chain-length esters from dibutyl through butyloctyl and dicyclohexyl phthalates are used as plasticizers in vinyl acetate emulsion systems. The lower aliphatic alcohol esters (methyl, ethyl, and butyl phthalates) and the glycolate-phthalate esters are used for plasticizing cellulose esters. The methyl, ethyl, and butyl diesters are also used as insect repellents. In minute amounts, phthalic anhydride esters are used in the preparation of various classes of dyes and intermediates. The phthalate esters are also used in food wrappings, furnishings for homes, automobiles, airplanes, some building materials, and as solvents in certain cosmetic formulations.

IV. Toxicity Information

A. Target organs: In case of inhalation, irritation of eyes, nose, and respiratory tract were noted. Ingestion caused gastrointestinal irritation and nephritis.

B. LD50 Values:

Dimethyl phthalate:

Mouse - oral 7.20 g/kg
ip 1.58-3.98 g/kg
Rat - oral 6.90 g/kg
ip 4.01 g/kg
Rabbit - oral 4.40 g/kg
skin 11.89 g/kg
Guinea pig - oral 2.40 g/kg
Chicken - oral 8.50 g/kg

Diethyl phthalate:

Mouse - ip 2.80-3.22 g/kg
Rat - ip 5.68 g/kg
Rabbit - oral 1.00 g/kg
Guinea pig - subcut 3.00 g/kg

Dibutyl phthalate:

Mouse - ip 3.57 g/kg
Rat - oral 8.00 g/kg
im >8.00 g/kg
ip 3.19 g/kg
Rabbit - skin 20.93 g/kg

Dimethoxyethyl phthalate:

Mouse - ip 4.18 g/kg
oral 3.20-6.40 g/kg
Rat - ip 4.37 g/kg
oral >4.40 g/kg
Guinea pig - oral 1.60-3.20 g/kg
skin 11.71 g/kg

Dibutoxyethyl phthalate:

Rat - oral 8.40 g/kg

Diallyl phthalate:

Mouse - ip 0.70 g/kg
Rat - oral 1.70 g/kg
Rabbit - oral 1.70 g/kg
skin 3.81 g/kg

Diisodecyl phthalate:

Mouse - ip >100 g/kg

Diisobutyl phthalate:

Mouse - ip 3.99 g/kg

Dioctyl phthalate (DOP):

Mouse - ip 65.70 g/kg
Rat - ip 48.90 g/kg

Di-2-ethylhexyl phthalate (DEHP):

Mouse - ip 37.77 g/kg
Rat - ip>49.25 g/kg

Ethyl carbethoxymethyl phthalate:

Mouse - ip 4.38 g/kg

Butyl carbobutoxyethyl phthalate:

Mouse - ip 6.88 g/kg
Rat - ip 7.56 g/kg

C. Acute/subchronic effects:

Up to the present, published literature on phthalate esters has indicated that these esters possess relatively low toxicities and should not present significant health hazards to man. Animal experiments have shown that the most frequently used phthalate esters have an extremely low order of acute toxicity. Lethal effects from absorption through the skin of guinea pigs and rabbits are also quite low. The phthalate esters produce little irritant response when placed in contact with animal and human skin. Few reports have indicated the irritant properties of these compounds on the eyes, nose, and respiratory tract with repeated exposures.

D. Long-term effects:

Some chronic nephritic changes and slight growth depression were observed in female rats by feeding methyl phthalate at doses of 4 or 8% of the diet for 2 years. Symptoms of gastrointestinal irritation with some coma and hypotension were also reported. Prolonged inhalation of phthalate esters may lead to central nervous system depression and paralysis. In two chronic feeding studies, it was observed that a dietary concentration of di-2-ethylhexyl phthalate below 0.13% had no effect in rats during a 2-year feeding period. However, there was some growth retardation and increase in liver and kidney weights at the 0.4 or 0.5% feeding concentration.

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction:

One report has indicated that di-2-ethylhexyl phthalate at a dose of 43.2 g/kg given orally to rats for 96 weeks produced tumors. Singh et al (1974), using dominant-lethal assay, reported that both di-2-ethylhexyl and dimethoxyethyl phthalates produced mutagenic effects in mice at the higher doses. Teratogenic effects of some phthalic acid esters have been reported in chicks by Haberman and his associates in 1967, 1968, and 1970 when the phthalates were injected into the yolk sac of developing embryos. Demonstration of mammalian teratogenicity has been reported by Singh et al (1972) from ip injections of the phthalate esters into pregnant rats.

F. Epidemiologic Studies:

No reports concerning epidemiologic studies of the phthalate esters were found in the published literature. Research in these areas should be initiated.

V. Standards

The recommended TLV of 5 mg/cu m for each diethyl, dibutyl, dimethyl, and di-2-ethylhexyl phthalates was reported by the ACGIH in the 1976 TLV list.

VI. Environmental Data

Inhalation of high concentrations of the phthalates may cause irritation of eyes, nose, and upper respiratory tract. Avoidance of skin contact and inhalation of mist, dust, or vapor is desirable. Cagianut (1954), reported by Fairhall (1957), observed that a 10 g ingestion of dibutyl phthalate by a chemical operator caused nausea, dizziness, lachrymation, photophobia, and conjunctivitis. Some albuminuria was also noticed. However, the patient made a prompt recovery.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Phthalic anhydride esters, unclassified	50,000
Dibutyl phthalate	1,000,000
Diisodecyl phthalate	100,000
Dimethyl phthalate	25,000
n-Octyl n-decyl phthalate	15,000
Diisooctyl phthalate	5,000
Diethyl phthalate	5,000
Diisobutyl phthalate	5,000
Dicyclohexyl phthalate - less than	5,000
Dioctyl isophthalate	30,000

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BARIUM AND ITS COMPOUNDS

I. Description

A review of production and consumption data has shown the following barium compounds are industrially important:

Barium sulfate
Barium sulfide
Barium carbonate
Barium hydroxide
Barium oxide
Barium chloride
Barium nitrate
Barium peroxide
Barium acetate
Barium stearate

Since barite is highly insoluble, most Ba chemicals are produced commercially from the more soluble black ash which is prepared as follows:

II. Production

A. Manufacturing processes

Barium sulfide (Black ash)

$$BaSO_4 + 4C \rightarrow BaS + 4CO$$

Most black ash solution is consumed captively for the production of the following chemicals:

Barium carbonate (synthetic)

$$BaS + Na_2CO_3 \rightarrow BaCO_3 + Na_2S$$

$$BaS + CO_2 + H_2O \rightarrow BaCO_3 + H_2S$$

Barium oxide

$$BaCO_3 \rightarrow BaO + CO_2$$

Barium hydroxide is produced by dissolving Barium oxide in water, removing the impurities, and concentrating the hydroxide.

Barium chloride

$$BaS + 2HCl \rightarrow BaCl_2 + H_2S$$

Barium sulfate (synthetic) M blanc fixe

$$BaS + Na_2SO_4 \rightarrow BaSO_4 + Na_2S$$

B. Production

The minerals barite (crude barium sulfate) and witherite (crude natural barium carbonate) provide the raw materials for production of the majority of barium chemicals. Of the 1,592 short tons of barite sold or used by producers in 1973, 7 percent was used for production of other barium chemicals. Most witherite is consumed for barium carbonate synthesis. The barium compounds produced on a tonnage basis are barium sulfide, barium carbonate, barium sulfate, barium chloride, barium oxide and hydroxide, and barium peroxide.

In 1973, 50,000 short tons of barium carbonate were produced in the United States of which 18,000 were used to produce other barium chemicals, the majority being barium oxide and barium hydroxide. In 1967, 111,000 short tons of barium sulfide and 11,200 short tons of barium chloride were produced. Domestic production of barium hydroxide was an estimated 6,000 short tons in 1974, while the merchant demand for the chemical was 15,000 short tons with imports making up the difference. Barium and Chemicals, Inc., Chemical Products Corp., Mallinckrodt, Inc., and Richardson-Merrell, Inc. are the principal producers of barium chemicals as of 1976.

III. Uses

Barium metal, being relatively volatile and readily distilled, plays an important part in extractive metallurgy. The most common use of barium is as a "getter" to remove the last traces of gas from thermionic valves (radio tubes).

Consumption of barium carbonate has declined for all major end uses in the last few years. There are five main uses for barium carbonate:

1. as a raw material for production of other barium compounds, in 1973 this accounted for 40 percent.

2. as a purification medium for the removal of all sulfates from aqueous solutions, with the precipitate of heavy-metal, alkaline earth metal, and magnesium ions.

3. acts as a flux in ceramics (about 25 percent)

4. as an ingredient in optical glasses and fine glassware (45 percent).

5. acts as a carbon carrier in case-hardening baths.

An estimated 7 percent of the barium carbonate consumed was as a raw material in the manufacture of barium-titanate and sintered mixtures with Fe_2O_3, known as barium ferrites. They are used in transducers for sonar detection and the ordinary ceramic phonograph cartridge. They are inexpensive magnetic materials, and the use for barium ferrites may grow eventually to sizeable proportions.

Synthetic barium sulfate is used as a pigment extender in paints and as a filler for textiles, rubber and plastics. Chemically precipitated barium sulfate, known as blanc fixe, is used in high quality paint, x-ray diagnostic work, glassmaking and papermaking. A look at the 1973 and previous consumption figures for this chemical indicates an upward trend.

Barium chloride is commercially available as $BaCl_2 \cdot 2H_2O$ and its primary use is as a raw material for the formation of blanc fixe for photographic paper, leather and cloth, as a raw material in the formation of barium colors, as an ingredient in case-hardening and heat-treating baths, as a flux in the manufacture of Magnesium metal, and as a laboratory reagent.

Barium hydroxide is commercially available as $Ba(OH)_2 \cdot 8H_2O$ and has recently increased in importance due to its use in preparing barium soaps (ingredients in high temperature greases). It is also used in glass manufacture, synthetic rubber vulcanization, lubricants, pesticides, the sugar industry, and animal and vegetable refining. Barium oxide also has an important use in the manufacture of lubricating oil detergents. However with car manufacturers now recommending less frequent oil changes, along with development of other oil additives, tonnage requirements of barium oxide and hydroxide may not increase in proportion to the increasing number of automobiles in service.

IV. Toxicity Information

A. Target organs: Central nervous system, heart, and gastro-intestinal organs.

B. LD50 and LDLO Values:

Barium sulfate:

Rat - oral, LDLO 630 mg/kg
Dog - oral, LDLO 400 mg/kg
Human - oral, LDLO 57 mg/kg

Barium sulfide:

None found

Barium carbonate:

Rat - oral, LDLO 630 mg/kg
Dog - oral, LDLO 400 mg/kg
Human - oral, LDLO 57 mg/kg

Barium hydroxide

None found

Barium oxide

Mouse - subcutaneous, LDLO 20 mg/kg

Barium chloride

Human - oral, LDLO 80 mg/kg
Rat - oral, LDLO 335 mg/kg
- subcutaneous, LD50 178 mg/kg
- intravenous, 20 mg/kg
Mouse - intraperitoneal, LD50 54 mg/kg
- subcutaneous, LDLO 10 mg/kg
- intravenous, LD50 12 mg/kg
Dog - oral, LDLO 90 mg/kg
- subcutaneous, LDLO 15 mg/kg
- intravenous, LDLO 26 mg/kg
Cat - subcutaneous, LDLO 38 mg/kg
- intravenous, LDLO 50 mg/kg
Rabbit - oral, LDLO 170 mg/kg
- subcutaneous, LDLO 55 mg/kg
- intravenous, LDLO 17 mg/kg
Guinea Pig - subcutaneous, LDLO 55 mg/kg

Barium sulfonates:

Rat - oral, LDLO 3000 mg/kg

Barium peroxide

Mouse - subcutaneous, LDLO 100 mg/kg

C. Acute/Subchronic effects:

Barium metal, due to its extreme reactivity in the presence of oxidizing gases, is considered a definite toxic material. The soluble barium compounds are toxic also. The barium ion is a muscle stimulant, regardless of the innervation. It is very toxic to the heart, resembling digitalis in its action, and may cause ventricular fibrillation. Symptoms include excessive salivation, vomiting, colic, violent diarrhea, convulsive tremors, hard pulse, high blood pressure, and renal, intestinal and stomach hemorrhage. The fatal dose of the chloride is 0.8 to 1.0 g; larger doses of the less soluble sulfide and carbonate may be tolerated. Water-soluble barium salts are readily absorbed from the gastrointestinal tract and are extremely toxic, inducing local irritation, peripheral vasoconstriction, digitalis-like action on the heart, violent peristalsis, and paralysis of the central nervous system.

D. Long-term effects

Chronic poisoning was reported by the injection of aqueous solution of barium chloride at doses of 2, 5, and 10 mg/kg in rabbits for 193 days. Effects on the central nervous system were observed.

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction:

No report regarding possible carcinogenic, mutagenic, teratogenic or other reproductive effects of barium and its compounds was found.

F. Epidemiologic studies:

No report involving epidemiologic studies of barium was found. Further investigation of the literature is suggested.

V. Standards

Barium sulfate MAC USSR 5 mg/cu m
Barium oxide TWA 500 ug/cu m
Barium chloride TLV ACGIH 0.5 mg/cu m
TWA 800 ug/cu m occupational stand USOS-air
Barium hydroxide TLV ACGIH 0.5 mg/cu m
Barium nitrate TLV ACGIH 0.5 mg/cu m
TWA air 952 ug/cu m

Tolerance for all barium compounds, except the sulfate, is 0.5 mg/cu m in air.

VI Environmental data:

Industrial exposures to barium compounds have indicated that these compounds produce pulmonary nodulation with or without decrease in lung function, such as dyspnea on exertion. More soluble forms of barium, such as the carbonate, oxide, and nitrate are more injurious. Barium oxide dust is considered to be a potential dermal and nasal irritant.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Barium sulfonate	2,800,000
Barium phenate	2,300,000
Barium sulfate	900,000
Barium carbonate	200,000
Barium alkyl phenolate	115,000
Barium phosphite	35,000
Barium oxide	30,000

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GLYCOL ETHERS

I. Description

This class of compounds includes cellosolves, carbitols and polyglymes. Cellosolves include monoalkyl ethers of ethylene glycol, carbitols are monoalkyl ethers of diethylene glycol, and polyglymes are dimethyl ethers of di- or triethylene glycol, diglyme and, triglyme. The mono-dialkyl ethers of ethylene glycol and diethylene glycol are very useful as high-boiling solvents.

A review of production and consumption figures for 1975, has shown the following glycol ethers to be of industrial importance:

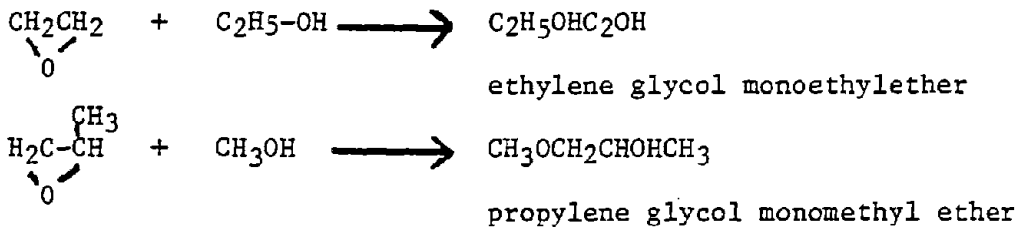
Compound	Production in Millions of Pounds in 1975
Ethylene glycol monoethyl ether	(170 million lbs)
Ethylene glycol monomethyl ether	(80 million lbs)
Ethylene glycol monobutyl ether	(140 million lbs)
Diethylene glycol monomethyl ether	(12 million lbs)
Diethylene glycol monoethyl ether	(28 million lbs)
Diethylene glycol monobutyl ether	(25 million lbs)
Triethylene glycol monomethyl ether	(31 million lbs)
Triethylene glycol monoethyl ether	(20 million lbs)
Triethylene glycol monobutyl ether	(25 million lbs)
Propylene glycol monomethyl ether	
Dipropylene glycol monomethyl ether	
Tripropylene glycol monomethyl ether	

II. Production

There were approximately 561 million pounds of glycol ethers produced in the year of 1975. In the year 1974-1975, ethylene glycol monoethers represented 75% of the total production.

The production of glycol ethers is expected to grow from 865 million pounds in 1976 to 985 million pounds in 1978. The major producers in this country are Dow Chemical, Jefferson Chemical Company, Inc., Union Carbide Corporation, and Shell Chemical Company.

The main production processes are as follows:



III. Uses

Glycol ethers consumption or uses in the year 1975 were as follows: Solvents and protective coatings 32%, solvents in hydraulic fluid 14%, printing inks, textile dyeing, etc., 27%, chemical intermediates 18-19%, jet fuel additives 8%.

IV. Toxicity Information

The toxicity data mainly were derived from animal studies. As a group, the oral toxicity to rats was low. The skin absorption in rabbits varied from very little to readily absorbed. This group of compounds when inhaled was slightly toxic with the exceptions of ethylene glycol monomethyl ether and ethylene glycol monoethyl ether. Eye injury to rabbits varied from trace to severe data in animals and humans.

The toxicity of each individual compound is summarized as follows:

Ethylene glycol monoethyl ether

- low in oral toxicity
- Rat - oral, LD50 3.0 g/kg
- Rabbit - oral, LD50 3.1 g/kg
- Mouse - oral, LD50 4.3 g/kg
- Mouse - i.p. LD50 1.7 g/kg
- Guinea Pig - LD50 1.4 g/kg
- Rat - inhalation LCLO 4000 ppm (4 hrs)
- Mouse - inhalation LCLO 1820 ppm
- irritating to eyes and mucous membranes
- readily absorbed through the skin
- somewhat toxic when inhaled, congestion of lung
- target organ: blood

Ethylene glycol monobutyl ether

- moderate oral toxicity
- Rat - oral, LD50 1.48 g/kg
- Mouse - oral, LD50 1.23 g/kg
- Rat - i.p. LD50 0.55 g/kg
- Rat - i.v. LD50 0.34 g/kg
- Mouse - i.p. LD50 o.54 g/kg
- Mouse - i.v. LD50 1.1 g/kg
- Rabbit - oral, LD50 0.32 g/kg
- Rabbit - skin, LD50 0.56 g/kg
- Rabbit - i.v. LD50 0.28 g/kg
- Guinea Pig - oral, LD50 1.2 g/kg
- Guinea Pig - Skin, LD50 0.23 g/kg
- Mouse - inhalation LC50 700 ppm (2 hrs)
- Rat - inhalation LC50 500 ppm (4 hrs)

- irritating and injurious to the eyes
- readily absorbed through the skin in toxic amounts
- moderate inhalation toxicity
- metabolized to butoxyacetic acid which is excreted in the urine
- substance and metabolite are hemolytic agents
- other target organs: kidney, liver

Ethylene glycol monomethyl ether

- low in single dose oral toxicity; moderate toxicity with repeated oral exposure

Rat - oral, LD50 2.5 g/kg
Guinea Pig - oral, LD50 0.95 g/kg
Rat - i.v. LD50 2.1 g/kg
Rabbit - oral, LD50 0.84 g/kg
Rabbit - skin LD50 1.34 g/kg
Rabbit - inhalation LC50 1.34 g/kg
Rat - inhalation LCLO 2.0 g/kg

- fairly ittitating to mucous membrane
- readily absorbed through the skin in toxic amounts
- appreciably toxic when inhaled (human)
- concentrations that may have serious toxic effects upon repeated and prolonged inhalation have negligible warning properties
- target organs: brain, blood, kidneys

Diethylene glycol monobutyl ether

- low single dose oral and vapor toxicity

Mouse - i.v., LD50 0.85 g/kg
Guinea Pig - oral, LD50 2.0 g/kg

- moderate repeated dose oral toxicity
- moderately irritating and injurious to the eyes
- absorbed through the skin in acutely toxic amounts only at large dosage levels
- material may be quite toxic when inhaled or absorbed through the skin in repeated small doses

Triethylene glycol monomethyl ether

Rat - oral, LD50: 11g/kg
Rabbit - skin, LD 50: 7100 mg/kg

- aquatic toxicity rating: TLM96: over 1000 ppm

Triethylene glycol monoethyl ether

Rat - oral, LD50: 10.6 g/kg
Rabbit - skin, LD50: 8 ml/kg
Rat - oral, no effect level: .75 g/kg/d for 30d

- no appreciable hazard in ordinary handling or use

Triethylene glycol monobutyl ether

Rabbit - skin, LD50: 354 mg/kg

Diethylene glycol monomethyl ether

- low oral toxicity
Guinea Pig - oral, LD50 4.2 g/kg
- painful but not seriously injurious to the eyes
- severe exposure required to absorb seriously toxic amounts through the skin
- hazardous amounts not likely to be inhaled under ordinary conditions, but cautionary measures should be taken when heated material is encountered

Diethylene glycol monoethyl ether

- low oral toxicity
Rat - oral, LD50: 8.69 g/kg
Guinea Pig - oral, LD50: 3.67 g/kg
Rat - i.v. LD50: 2.9 g/kg
Mouse - s.c. LD50: 5.6 g/kg
Mouse - i.v. LD50: 3.4 g/kg
Dog - i.v. LD50: 3.0 g/kg
Rabbit - s.c. LD50: 2.0 g/kg
Rabbit - s.c. LD50: 0.90 g/kg
Guinea Pig - oral, LD50: 3.1 g/kg
Rat - s.c. LDLO: 2.0 g/kg
- readily absorbed through the skin
- low volatility; acutely hazardous vapor concentrations do not occur at ordinary temperatures

Dipropylene glycol monomethyl ether

- low single dose oral toxicity
Rat - oral, LD50: 5.45 ml/kg
Dog - oral, LD50: 7.5 ml/kg
- low inhalation toxicity
- transiently painful to eyes

Propylene glycol monomethyl ether

- low single-and repeated-dose oral toxicity
Rat - oral, LD50: 6.6 g/kg
Dog - oral, LD50: 10 ml/kg
- transiently painful to eyes
- can be absorbed through the skin in toxic amounts if exposure is extensive and prolonged
- low vapor toxicity; vapors essentially intolerable to humans at low concentrations
- primary effect: anesthetic agent

Tripropylene glycol monomethyl ether

Rat
- low single-dose oral toxicity
- oral, LD50: 3.3 g/kg
- transiently painful to the eye
- irritating to the skin only if exposure is severe
- can be absorbed through the skin in toxic quantities if exposure is prolonged and repeated
- low vapor pressure precludes inhalation of toxic quantities during single or repeated exposure
- apparently negligible hazards to health from ordinary handling and use
- primary effect: narcotic

V. Standards

Standards for occupational exposure to airborne substances have been established for ethylene glycol monbutyl ether (TLV of 50 ppm), ethylene glycol monomethyl ether (TLV 25 ppm - skin), and dipropylene glycol monomethyl ether (TLV 100 ppm - skin).

None of these groups of compounds was listed as suspected carcinogen. No report was made on mutagenicity or teratogenicity caused by these compounds.

VI. Environmental Data

None was found.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Glycol ethers, unclassified = 2,616,000

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RUBBER PROCESSING CHEMICALS

I. Description

The U.S. Tariff Commission defines rubber-processing chemicals as "organic compounds that are added to natural and synthetic rubbers to give them qualities necessary for their conversion to finished rubber goods". The rubber chemicals can be grouped into 3 categories:1) accelerators of the vulcanization process;2) antioxidants and stabilizers;and 3) miscellaneous materials (wax, blowing agents, activators, plasticizers, etc.)

Accelerators are usually organic compounds that reduce the time required to vulcanize synthetic and natural rubber. These compounds are also effective in reducing the aging of the rubber and giving appropriate physical properties to the finished rubber product. The introduction of organic accelerators in the early twenties was largely responsible for the advancement of the tire industry.

Antioxidants and stabilizers are organic compounds added to the synthetic rubber to keep the chemical process controlled. These compounds act to:1) keep a mixture from changing its form or chemical nature; 2) retard the reaction rate; 3) preserve a chemical equilibrium and;4) stabilize pigments. These processing chemicals enable the rubber manufacturer to tailor the process in order to yield the specific characteristic desired in the rubber.

The final grouping includes miscellaneous materials used in relatively low volumes to either finish the rubber or add to its strength and flexibility. These compounds include waxes, blowing agents, activators, and chemical plasticizers.

II. Production and Use

The various combinations and quantities of these compounds used in the rubber manufacturing process dictate the strength, flexibility, opacity, and resiliance of the final product.

1) Accelerators (in order of production volume)

Thiazole derivatives - 94.6 million lbs, 1973

- N-cyclohexyl-2-benzothiazole sulfenamide
- 2,2 -dithiobis (benzothiazole)
- 2 -mercapto benzothiazole
- 2 -mercapto benzothiaole sulfenamide
- "other" - 63.5 million lbs - no specific production information available

  - mercapto benzothiazole: mentioned in Zenz as causing dermatitis
  - 2 -Benzothiazyle N,N-diethylthiocarbamoyl sulfide
  - N-tert-Butyl-2-benzothiazole sulfenamide
  - N,N-Diisopropyl-2-benzothiazole sulfenamide

- N-(2,6-Dimethylmorpholino)-2 benzothiazole sulfenamide
- 2-Mercapto benzothiazole, copper salt and zinc chloride
- 4-Morpholinyl-2-benzothiazyl disulfide
- N-Oxcydiethylene-2-benezothiazole sulfenamide

Thiurams - 23.3 million lbs, 1973

- Bis (diethyldithio carbamoyl disulfide)
- Bis (dimethylthio carbamoyl) sulfide
- tetramethyl thiuram disulfide

Dithiocarbamates - 11 million lbs produced, 1973

- dibutyldithiocarbamic acid, zinc salt
- diethyldithiocarbamic acid, zinc salt
- dimethyldithiocarbamic acid, zinc salt

Aldehyde-amine reaction products - 1.97 million lbs, 1973

Guanidines - no production information given, but probably very low

- >800,000 lbs

2) Antioxidants and Stabilizers

Amino Compounds - 138 million lbs produced, 1973

aldehyde and acetone-amine reaction products - 8.6 million pounds

- no specific production information provided on individual compounds; included in this group are:

  acetaldehyde - aniline hydrochloride condensate
  butyraldehyde - aniline condensate
  diphenylamine - acetone condensate
  phenyl-2-naphthylamine - acetone condensate

substituted p-phenylenediamines - 71.8 million lbs, 1973

N,N - diphenyl-p-phenylenediamine
"Other," with no specific production information;comprises 70.5 million lbs. Compounds included in this group are:

N,N'-Bis(1,3-dimethylbutyl)-p-phenylenediamine
N,N'-Bis(1,4-dimethylpentyl)-p-phenylenediamine
N,N'-Bis(1-ethyl-3-methylpentyl)-p-phenylenediamine
N,N'-Bis(1-methylheptyl)-p-phenylenediamine
N-sec-Butyl-N'-phenyl-p-phenylenediamine
Diarylarylenediamines, mixed
N,N'-Dicyclohexyl-p-phenylenediamine
N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine
N,N'-1,4-Dimethylhexyl-p-phenylenediamine
N,N'-Di-2-naphthyl-p-phenylenediamine
N-Isopropyl-N'-phenyl-p-phenylenediamine
N-(1-Methylheptyl)-N'-phenyl-p-phenylenediamine

N-(1-Methylpentyl)-N'-phenyl-p-phenylenediamine
All other substituted p-phenylenediamines

These lists are taken from the 1973 U.S. International Trade Commission issue of Synthetic Organic Chemicals, U.S. Production and Sales

- "Other" amino compounds - 527 million lbs, 1973

N-phenyl-2-naphthylamine - 4.9 million lbs
No specific production figures are available, but compounds in this class include:

p-Anilinophenol
1,2-Dihydro-6-dodecyl-2,2,4-trimethylquinoline
1,2-Dihydro-6-ethyoxy-2,2,4-trimethylquinoline
1,2-Dihydro-2,2,4-trimethylquinoline
4,4'-Dimethyoxydiphenylamine
Dinonyldiphenylamine
N,N'-Diphenylethylenediamine
N,N'-Diphenyl-1,3-propanediamine
N,N'-Di-o-tolylethylenediamine
p-Hydroxydiphenylamine
4-Isopropoxydiphenylamine
4,4'-Methylenedianiline
Nonyldiphenylamine mixture (mono-, di-, and tri-)
Octyldiphenylamine
Octyldiphenylamine, alkylated
N-Phenyl-1-naphthylamine
'N-Phenyl-2-naphthylamine
'p-(p-Toluenesulfonamide) diphenylamine

Phenolic Compounds - 27.64 million lbs, 1973

Polyphenolics (including bisphenols) - 15.6 million lbs
- no specific production figures, but compounds include:

Bisphenol, hindered
4,4-Butylidenebis(6-tert-butyl-m-cresol)
2,5-Di-(1,1-dimethylpropyl)hydroquinone
2,5, Di-sec-butyldecylhydroquinone
3,7-Dioctylphenothiazine
2,2'-Methylenebis(6-tert-butyl-p-cresol)
2,2'-Methylenebis(6-tert-butyl-4-ethylphenol)
2,2'-Methylenebis(6-(1-methylcyclohexyl)-p-cresol)
2,2'-Methylenebis(6-tert-octyl-p-cresol)
2,2'Thiobis(4,6-di-sec-amylphenol)
4,4'-Thiobis(6-tert-butyl-m-cresol)
Thiobisphenol, alkylated
1,1,3-Tri(2-methyl-4-hydroxy-5-tert-butylphenyl)-butane

- 2,2-methylene-bis (4-methyl-6-tertiarite butylphenyl)

Phosphite compounds - 48.65 million lbs, 1973

Alkylaryl phosphites, mixed
Nonyl phenyl phosphites, mixed
Polymeric phosphite
Polyphenolic phosphite, polyalkylated
Triaryl phosphites

3) Miscellaneous Materials

Peptizen (plasticizers) - 3.65 million lbs, 1973

thio beta-naphthol
2-Benza idothiophene, zinc salt
2',2'''-Dithiobis(benzanide)
Dixylyl disulfides, mixed
2-Naphthalenethiol
Pentachlorobenzenethiol
Pentachlorobenzenethiol, zinc salt
Xylenethiol

Blowing Agents

Sodium bicarbonate - 1966 production=3.7 million lbs
Stearic acid
4,4'-Biphenylene bis(sulfonylhydrazide)
N,N -Dimethyl-N,N1-dinitrosoterephthalamide
Dinitrosopentamethylenetetramine
p,p'-Oxybis(benzenesulfonhydrazide)
p-Toluenesulfonylhydrazide
p-Toluenesulfonylsemicarbazide
azodicarbonamide

Retardants

- most common:

phthalic anhydride
benzoic acid
salicylic acid
maleic acid
maleic anhydride
terpene-resin acid blend
vulcatard
curetard
N-nitrosodiphenylamine 2.5 million lbs, 1973

Vulcanizing agents - (no production or consumption data)

- sulfur, elemental
- tetramethylthiuram disulfide
- tetraethylthiuram disulfide
- dipentamethylenethiuram tetrasulfide
- 4,4'-dithiodimorpholine
- selenium diethyldithiocarbamate
- aliphatic polysulfide polymer
- alkyl phenol disulfides
- p-quinonedioxime

III. Toxicity Information

a) Thiazole Derivatives

LD50 - mice - oral - range from 2000 mg/kg to 75 mg/kg

b) Thiurams; Bis(Dimethylthiocarbamoyl)

Thiurams are relatively nontoxic substances except for the synergistic reaction of thiurams and alcohol. Exposure to alcohol and thiurams together increases the acetaldehyde concentration in humans causing nausea, copious vomiting, sweating, and chest pains.

LD50			
rats	-	oral	- 560 mg/kg
mice	-	oral	- 1350 mg/kg
man	-	unknown	- 780 mg/kg

c) Dithiocarbamates (Zinc salt)

The soluble salts of zinc that ionize most completely, such as zinc chloride, are quite irritating and can be used as escharotics. If taken internally, the zinc salts irritate the gastric mucosa and cause vomiting; on this basis zinc sulfate has been used as an emetic. Exposure to mists and fumes of zinc salts may give rise to irritation of the respiratory and gastrointestinal tracts.

LD50

rat	-	i.p.	- 40 mg/kg
mouse	-	i.p.	- 29 mg/kg
rabbit	-	scu	- TDL_o 2.5 mg/kg

2) Antioxidants and Stabilizers

a) Acetaldehyde

Acetaldehyde is extremely flammable and has a general narcotic effect on the central nervous system.

LD50

rat - oral - 1.93 g/kg
rat - s.c. - 0.64 g/kg

Inhalation toxicity

Species	PPM	TIME	MORTALITY
rat	sat. vap.	2 min.	LC100
rat	16,000	4 hrs.	0/6
rat	20,000	30 min.	LC50
cat	13,600	0.25 hr.	1/1

- At 50 ppm a majority of volunteers exposed for 15 mins. showed some sign of eye irritation. At 200 ppm all subjects had red eyes and irritation.

- Human subjects were given intravenous infusions to raise the blood level of acetaldehyde to 0.2 to 0.7 mg% (about 10 times normal). At these levels an increase in heartrate and respiratory ventilation occurs, and a hangover sensation is noted.

b) Phenolics

The main hazard due to the phenolic group stems from exposure to phenol which may cause dermatitis and changes in the mucous membrane (simple irritation or sensitization)

LD50

rats - skin - 699 mg/kg
rats - i.p. - 250 mg/kg
mice - s.c. - 344 mg/kg

c) Phosphites

Triphenyl Phosphite

- Studies with rats showed LD50's with oral administration to be 1.6-3.2g/kg. Tremors, diarrhea, and vasodilatation by all routes was observed in the rats during this experiment.

- Skin and eye irritations were caused at concentrations of 1.6-3.2 g/kg in a guinea pig study.

3) Miscellaneous Materials

a) Xylene (plasticizer)

Xylene is moderately toxic by ingestion and is suspected to cause skin irritation.

- Rabbits and rats exposed to 690 ppm (3 mg/liter) of mixed xylenes, 8 hours per day, 6 days per week, for 130 days developed no significant changes in the peripheral blood. Rabbits exposed for 8 hours per day, 6 days per week, for 55 days at 1150 ppm (5.0 mg/l) to mixed xylenes developed a decrease in the number of red blood cells and leucocytes and an increase in the platelet count.

b) Stearic Acid (blowing agent)

LD 50

rat	-	iv	22 mg/kg
mouse	-	iv	23 mg/kg
cat	-	iv	5 mg/kg

- Stearic acid has been known to migrate into foodstuffs from packaging materials, however data on the toxicity of this compound was not found in the published literature except for the LD50 studies.

c) Benzoic Acid (retarder)

Benzoic acid has acute toxicity in rats, however its effect on human skin is only mildly irritating.

LD50

rats - skin - 1700 mg/kg

Daily intake of 4-6 grams does not cause toxic symptoms in humans aside from slight gastric irritation.

IV. Epidemiologic and Environmental Data

A study was conducted by the Occupational Health Studies Group at the University of North Carolina, Chapel Hill, NC, which investigated a tire manufacturing plant using a hexamethylene tetramine resin (HR) system. This resin system is typical of those used in the rubber industry. Symptoms of skin and respiratory problems of both a chronic and an acute nature were studied by questionnaire.

In the group studied, there was no statistically significant difference in chronic respiratory and cardiovascular symptoms. However, the reported symptoms of itch, rash, breathing, cough, chest tightness, burning eyes, running nose, and heartburn were significantly increased in workers exposed to the HR system. HR exposed groups experienced more respiratory symptoms than unexposed groups, and drinking was found to be closely associated with these symptoms.

V. Standards

- U.S. Occupational Standard for Thiuram (Tetramethylthiuramdisulfide) (air): TWA: 5 mg/cu m (air, TWA)

- ACGIH TLV (1976) for Zinc Chloride fume - 1 mg/cu m

- ACGIH TLV (1976) for Acetaldehyde - 100 ppm (180 mg/cu m)

- U.S. Occupational Standard for Triphenyl phosphite TWA - 1 mg/cu m (air, TWA)

- ACGIH TLV (1976) - 100 ppm (435 mg/cu m) skin

VI. Potential Exposure Estimates from the National Occupational Hazard Survey

Accelerators, unclassified -	500,000
Dithiocarbamates -	less than 30,000
Mercaptobenzothiaole -	450,000
Thiurams -	less than 30,000
Retarders, unclassified -	30,000
Vulcanizing agents, unclassified -	32,000

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PLASTICIZERS

I. Description

Plasticizers are organic compounds added to polymers to facilitate processing and to increase the flexibility and toughness of the final product by internal modification of the polymer molecule. The polymer molecule is held together by secondary valence bonds; the plasticizer replaces some of these aiding movement of the polymer chain segments. Plasticizers are classed as primary (high compatibility) and secondary(limited compatibility).

II. Production and Use

A large amount of plasticizers are used in polyvinyl compounds and cellulose esters, however, they are also used extensively in the synthetic rubber process.

Major Plasticizers in order of production importance are:

1) Phthalate esters (1,207 million pounds produced in 1974)

- dioctyl phthalates
- 2-ethylhexyl phthalate
- phthalate esters of linear alcohols
- diisodecyl phthalate
- butyl benzyl phthalate
- diisononyl phthalate
- dicyclohexyl phthalate
- butyl decyl phthalate
- ditridecyl phthalate
- dibutyl phthalate
- diethyl phthalate
- dimethyl phthalate

2) Epoxy Esters (147 million pounds produced in 1974)

- epoxidized soybean oils
- octyl epoxy tallates
- epoxidized linseed oil plasticizers

3) Phosphate esters (123 million pounds produced in 1974)

- tricresyl phosphate
- triisopropylphenyl phosphate
- cresyldiphenyl phosphate
- triphenyl phosphate
- 2-ethylhexyl diphenyl phosphate
- isodecyl diphenyl phosphate
- dibutyl phenyl phosphate
- triphenyl phosphate
- triethyl phosphate
- tri (2-butoxyethyl) phosphates
- trioctyl phosphate
- tributyl phosphate

4) Aliphatic esters (83 million pounds produced in 1974)

- di-2-ethylhexyl adipate (DOA)
- n-octyl n-decyl adipate
- diisodecyl adipate
- diisooctyl adipate
- di-2-butoxyethoxy ethyl adipate
- azeloic acid esters
- sebacic acid esters
    - dibutyl sebacate
    - di-2-ethylhexyl sebacate

5) Polymeric plasticizers (50 million pounds produced in 1974)

6) Other (70 million pounds produced in 1974)

- trimellitates
- benzoates
- pentaerythritol esters

III. Toxicity Information

1) Phthalate Esters

Reports indicate that the phthalate esters effect blood components in the human and guinea pig and exert a teratogenic effect upon chicks and rats. Major questions relating to the possible hazards of phthalates to humans are largely concerned with the subtle or delayed effects upon health, rather than acute or dramatic effects.

Acute Toxicity of Some Phthalate Esters

COMPOUND				LD50 VALUES	
Dimethyl phthalate	-	mice	-	i.p.	3.98 g/kg
Diethyl phthalate	-	mice	-	i.p.	3.22 g/kg
Di-n-butyl phthalate	-	mice	-	i.p.	3.57 g/kg
Diisobutyl phthalate	-	mice	-	i.p.	3.99 g/kg
Di-n-octyl phthalate (DOP)	-	mice	-	i.p.	65.70 g/kg

2) Epoxy Esters

The majority of observations indicate that physiologically three main effects are shown by epoxies:

A. central nervous system depression
B. irritation of surface tissues
C. radiomimetic action

One epoxy compound typical of those used in plasticizers is allyl glycidyl ether. This compound is a central nervous system depressant and also causes acute pulmonary edema. It is slightly toxic after oral administration, irritating to the eyes, and can cause skin irritation in human subjects.

LD50 values for allyl glycidal ether

mice - oral, 0.39 g/kg
rats - oral, 1.60 g/kg
rabbits - oral, 2.55 g/kg

The observed effects in man include irritation and occasional sensitization with this compound, also the possibility exists for cross-sensitization to other epoxy agents.

3) Phosphate Esters

A) Target Organs - central nervous system and gastrointestinal organs

B) LD50 values

Triisobutyl phosphate

rat - oral, 3.2 - 6.4 g/kg
rat - i.p., 0.8 - 1.6 g/kg

Tri-2-ethyl isohexyl phosphate

rat - oral, > 25.0 g/kg
rat - i.p., 6.4 - 12.8 g/kg

Tri-2-ethylhexyl phosphate

rat - oral, 37.0 g/kg
rat - i.p., 30.0 g/kg
mouse - oral, > 12.8 g/kg
mouse - i.p., 3.2 - 6.4 g/kg

C) Acute/Subchronic effects:

Studies with cats and dogs have shown that after large doses over a relatively short period of time flaccid paralysis of the posterior extremities and irritation of the skin and respiratory tract occur.

D) Long term Effects:

In the case of tri-o-cresyl phosphate toxicity, some serious gastrointestinal disturbances followed by paralysis of the feet, legs, arms, and hand were observed. Also muscular atrophy, sharp cramp-like pains, and numbness of the legs were observed.

In general, phosphate esters have been shown to produce the following toxic effects:

- organic damage to the CNS, resulting in flaccid or spastic paralysis
- convulsive or CNS stimulant action, or in some cases an anesthetic action
- relatively weak inhibition of true or pseudo-cholinesterase with the latter predominating
- irritation of the skin and respiratory surface

4) Aliphatic Esters

di-2-ethylhexyl adipate (DOA)

LD50 values:

rat - oral, 9.1 g/kg
rat - i.p., > 47 g/kg
mouse - i.p., approx. 150 g/kg
rabbit - i.p., > 38.0 g/kg
rabbit(skin)- 16.3 ml/kg

- a rat inhalation study showed no mortality after approximately 8 hrs. of saturation with di(2-ethylhexyl) adipate

- there is a "slight" irritation of the skin and eyes with exposure to vapors of this compound

5) Polymeric Plasticizers

No toxicity data were reported in the published literature which was searched.

IV. Epidemiological and Environmental Data

Phosphate Esters -

In 1930, an epidemic poisoning of tri-o-cresyl phosphate occured in which about 10,000-15,000 people developed a neuromuscular disturbance characterized by flaccid paralysis. There have been 8 or 9 epidemics since that time, and one occured in 1959 in Morrocco involving several thousand persons.

With the concentrations of aryl phosphates ranging from 0.2-3.4 mg/cu m, some occupational cases of polyneuritis and neurologic symptoms in workers from manufacturing various aryl phosphates were reported.

Avoidance of skin contact and inhalation of mist, dust, and vapor are recommended.

Standards: ACGIH (TLV)

Allyl glycidal ether, 5 ppm (22 mg/cu m)
Diethyl phthalate, 0.65 ppm (5 mg/cu m)
tri-o-cresyl phosphate, 0.1 mg/cu m

VI. Potential Exposure Estimates from the National Occupational Hazard Survey

Plasticizers	-	1,000,000
Epoxy Esters	-	75,000
Epoxidized soybean oil	-	45,000
Aliphatic esters	-	85,000
Adipic acid esters	-	75,000
Sebacic acid esters	-	75,000
Sebacate polyester plasticizer	-	100,000

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LUBRICANT, OIL, AND GREASE ADDITIVES

I. Description

Lubricant, oil, and grease additives are the compounds used to improve the characteristics of the products. These additives serve as: 1) detergents and dispersants, 2) oxidation and corrosion inhibitors, 3) viscosity-index improvers, 4) extreme pressure additives, and 5) antifoam agents.

Data on production showed that the following compounds are of commercial importance:

Acyclic compounds

Phosphodithioates
- -zinc di(butylhexyl) phosphodithioate
- -zinc dehexyl phosphodithioate
- -zinc diisopropyl phosphodithioate
- -2-piene phosphodithioate

Sulfurized Lard Oil
"Other" Acyclics
- -chlorosulfidized, phosporized, and sulfurized materials

Molybdenum disulfide
Triethanolamines
Polymethacrylate

Cyclic compounds

Petroleum Sulfonates
- -barium, calcium, and sodium salts

Other Cyclics
- -includes salts of oil soluble petroleum
- -phenol and alkylphenol salts (eg. barium and calcium alkyl phenolates) and calcium salts of octylphenolformaldehyde
- -chlorosulfidized and sulfurized additives

II. Production

A. Manufacturing

No information was available on the manufacturing processes.

B. Production

	Millions of lbs.	Year
Acyclic		
Phosphorodithioates	104	1971
Sulfurized Lard Oil	7.9	1971
"Other" acyclic	360.2	1971
Polymethacrylates	45-55	1974

	Millions of lbs.	Year
Cyclic		
Petroleum sulfonates		
Barium salts	16.9	1970
Calcium salts	105.8	1970
Sodium salts	64.8	1970
Other Cyclics	199	1971
Triethanol amine salt of alkyl - benzene sulfonate	3.3	1968

Production of the salts of dodecyl phenol in 1974 was 64 million pounds and is expected to increase at a rate of 4% annually for the years 1975-79.

III. Uses

The lubricant, oil, and grease additives are added to the product to improve the characteristics as follows:

a. Detergents and Dispersants - metallic salts of petroleum sulfonates

b. Oxidation and Corrosion Inhibitors - metal dithiophosphates, dithiocarbamate (primarily zinc)

c. Viscosity-Index Improvers - polymethacrylates

d. Extreme Pressure Additives - phosphorized and sulfurized organic compounds

e. Antifoam Agents - silicone polymers

IV. Toxicity Information

A. Target organs: The additives cause irritation to the skin and eyes.

B. LD50 Values:

Triethanol amine:

Guinea pig - oral 8.0 g/kg

C. Acute/subchronic effects:

This group of compounds vary in toxicity from very low to slightly toxic. They affect the skin and eyes producing irritation.

D. Long-term effects:

Long-term effects due to triethanol amine on repeated feeding to animals produced reversible damage in liver and kidneys.

E. Carcinogenicity, Mutagenicity, Teratogenicity, and Other Effects on Reproduction:

None have been reported.

F. Epidemiologic Studies:

None was available.

V. Standards

Compound ACGIH (TLV)	
Molybdenum as	
molybdenum soluble compounds	5 mg/cu m
molybdenum insoluble compounds	15 mg/cu m

VI. Environmental Data

None was available

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Triethanol amine	2,300,000
Molybdenum disulfide	2,600,000
Calcium salt of petroleum sulfonate	2,800,000
Barium salt of petroleum sulfonate	2,800,000

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PRIMARY AROMATIC AMINES

I. Description of Chemicals

The primary aromatic amines are defined as an aromatic hydrocarbon where at least one hydrogen atom is substituted by an amino ($-NH_2$) group. Usually this aromatic hydrocarbon is benzene.

These amines compared with the aliphatic amines share more similarities than differences. They are rather weak bases compared to ammonia or the aliphatic amines. In their physical state they exist as high boiling oily liquids or colorless crystalline solids. The primary aromatic amines are usually discolored since they are highly reactive to oxidation by light or air. Generally they are not soluble in water but are fat-soluble and are soluble in organic solvents. As aromatics they exhibit a low vapor pressure, moderate volatility and a characteristic aniline odor. These compounds are very rarely found but are synthesized readily.

A review of manufacturing processes and production data has shown the primary aromatic amines listed below to be industrially important. Those primary aromatic amines which are being reviewed by NIOSH for "Criteria Documents" have been excluded.

	CAS Number	Molecular Weight
Cyclohexylamine	000108918	99.20
Toluidine (o,p,m)	o-000095534	
	p-000106490	107.15
	m-00108441	
Alpha-Naphthylamine	000134327	143.20
Mesidine	000088051	135.23
Phenethylamine	000064040	121.18
Phenylenediamine (o,p,m)	o-000095545	
	p-000106503	108.16
	m-000108452	

II. Production

A. Manufacturing

Industrially the manufacturing process involves the nitration of the aromatic hydrocarbon to a nitro-compound and then the reduction of the compound to the amine by the reagents, iron and dilute hydrochloric acid or by catalytic hydrogenation. Also, used but occasionally, direct amination may be effected by reacting a chloro- or hydroxy- radical of the aromatic ring with ammonia under high pressure and temperature with a catalyst.

The reduction of aromatic nitro compounds is by far the most useful method of preparing amines, since it uses readily available starting materials and yields the most important kind of amines, primary aromatic amines. Primary aromatic amines, with aqueous mineral acids are converted into aromatic diazonium salts, which are among the most versatile class of organic compounds known. This sequence provides the best route to dozens of kinds of aromatic amines.

B. Production

Listed are the primary aromatic amines with the number of manufacturing companies and the number of companies distributing each compound. The most important producers of primary aromatic amines are Abbott Laboratories, Allied Chemical Corporation, E.I. duPont de Nemours & Co., Inc. and Virginia Chemical Company.

	Manufacture	Distributing
Cyclohexylamine	3	22
Toluidine (o,p,m)	5	27
Alpha-naphthylamine	3	22
Mesidine	NA	15
Phenethylamine	2	10
Phenylenediamine (o,p,m)	5	26

Production figures for primary aromatic amines are not inclusive or complete because this group of compounds is used as intermediates in organic synthesis. The importance of these compounds is in synthesis and not final product. Production figures which have been found are listed below:

		Million Pounds	Years
Cyclohexylamine		20	1974
Alpha-naphthylamine		1.1	1963
Phenylenediamine (o,p,m)		48(p)	1974
	gasoline antioxidant	2.5	1974
	rubber antioxidant	74	1974
	total (p)	73	1974

III. Uses

The main use of primary aromatic amines is in the organic synthesis of other organic compounds. They are used principally as intermediates. One of their largest uses as an intermediate is in the making of dyes (azo, thizane, saframines) and pigments. Other uses are as intermediates in insecticides, pharmaceuticals, rubber antioxidants, perfumes and elastomers, vulcaniziers, base for plastics and molding composition, epoxy resins, photography, rubber curing agents and as laboratory reagents.

IV. Toxicity Information

A. Target Organs

Primary aromatic amines affect the eyes, mucous membranes, respiratory tract, skin, bladder, kidney, CNS, and liver.

B. LD50 Values

Cyclohexylamine

hamster oral 50 mg/kg
rat oral 710 mg/kg
rat i.p. 200 mg/kg
mouse i.p. 300 mg/kg
rabbit skin 320 mg/kg
rabbit parental (LDLO) 500 mg/kg
rat inhalation (LCLO) 8000 ppm (4 hrs)

Toluidine

o-toluidine

mouse oral 870 mg/kg
rat oral 900 mg/kg
mouse i.p. 150 mg/kg
rabbit skin 3250 mg/kg
cat oral (LDLO) 300 mg/kg
frog oral (LDLO) 5 mg/kg

p-toluidine

mouse i.p. 50 mg/kg
wild bird oral 42 mg/kg
rat oral 650 mg/kg
mammal oral (LDLO) 100 mg/kg

m-toluidine

rat oral 974 mg/kg
mouse i.p. 150 mg/kg

Alpha-naphthylamine

rat oral 779 mg/kg
rabbit subcut (LDLO) 300 mg/kg
mammal oral (LDLO) 4000 mg/kg

Mesidine

rat oral 506 mg/kg
rat oral 660 mg/kg
mouse i.p. 338 mg/kg
mouse i.p. 260 mg/kg
mouse unknown 372 mg/kg
rabbit unknown 338 mg/kg
guinea pig unknown 338 mg/kg

Phenethylamine

mouse i.p. 366 mg/kg
mouse oral 400 mg/kg
rat oral (LDLO) 800 mg/kg
rat i.p. (LDLO) 100 mg/kg
mouse unknown (LDLO) 300 mg/kg

Phenhylenediamine

o-phenylenediamine

rat subcut (LDLO) 600 mg/kg
mouse subcut (LDLO) 600 mg/kg

p-phenylenediamine

rat oral (LDLO) 100 mg/kg
rat i.p. (LDLO) 50 mg/kg
rat subcut (LDLO) 170 mg/kg
dog subcut (LDLO) 100 mg/kg
dog iv (LDLO) 17 mg/kg
cat oral (LDLO) 100 mg/kg
rabbit oral (LDLO) 100 mg/kg
rabbit subcut (LDLO) 200 mg/kg
mammal iv (LDLO) 17 mg/kg

m-phenylenediamine

rat oral (LDLO) 80 mg/kg
dog iv (LDLO) 17 mg/kg
rat subcut (LDLO) 80 mg/kg
cat oral (LDLO) 300 mg/kg
rabbit oral (LDLO) 300 mg/kg
rabbit subcut (LDLO) 200 mg/kg

C. Acute/Subchronic Effects

The primary aromatic amines exert a profound biological effect at low dosages. They are readily absorbed through the skin or inhaled as dust, fume or vapor. The aromatic amines are characterized by a common

and outstanding property: the ability to form methemoglobin in man. They are not the only compounds that exhibit this effect but are among the strongest forming methemoglobin. A great deal of work has been done to try to explain the mechanism by which hemoglobin is oxidized, but it remains elusive as to whether the compound or its metabolites produce the effect. Typical symptoms are cyanosis; bluish discoloration of mucous membranes, lips and nails; headache; malaise; anoxia; and weakness. Prolonged exposure produces convulsions, psychic disturbances and depressed CNS which may cause death or permanent injury.

The amines also produce irritation of the eyes, skin and respiratory tract. Prolonged exposure leads to burning and dermatitis with inflammation of the respiratory tract which produces asthma-like symptoms. The primary amines also effect an allergic reaction, sensitizing to exposure. Other effects are hematuria, a painful and unpleasant hemorragic cystitis. This is only a tranisent effect and produced most effectively by the toluidine derivatives.

D. Long-term Effects

A number of aromatic amines used in industry have been proved and others suspected of causing tumors in the urinary tract, particularly the bladder. The toluidines and beta-naphthylamine have been directly linked with bladder cancer. Characteristically there is a latent period of many years after first exposure before the tumors develop, often many years after exposure has ceased. This period has varied in length from one to 40 years. The average latent period after first exposure is 18.5 years. Other primary aromatic amines under investigation for carcinogenic activity are cyclohexylamine and the phenylenediamines, particularly the p-isomer.

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction

Cyclohexylamine after intraperitoneal injections in rats caused chromosomal damage and a dose-dependent increase in chromosome breaks was noted. An adverse effect on fertility in male rats was noted with oral cyclohexylamine sulfate but no deleterious effect on embryo viability, litter size, litter weight, post natal viability, weight gain of pups, or on somatic cell chromosomes of pups and dams. Some have found it to be embryotoxic but those investigators using physiological dosages have found no effects in rats or rabbits on fertility, reproduction, embryogenesis and peri- and post-natal development. In an experiment using human subjects, cyclamate was fed at 5 gm per day for 7 to 8 days. Those subjects in whose urine cyclohexylamine was found were tested and no change in blood pressure, heart rate, or abnormalities in EKG were detected. It was concluded that no pharmacologically active levels of cyclohexylamine were reached in the tissues.

The toluidines have been demonstrated clearly by investigators to be carcinogens producing tumors in the bladder. The following neoplastic effects and dose response have been found for o-toluidine:

Neoplasm TDLO,	rat	oral	8200 mg/kg	(24 weeks)
	mouse	oral	870 mg/kg	(7 weeks)

OSHA has recognized alpha-naphthylamine as a carcinogenic causing bladder cancer. However, it is not known whether beta-naphthylamine exists as an impurity in alpha-naphthylamine. As yet for both alpha- and beta-naphthylamine the carcinogenic metabolite(s) have not been clearly defined. The following effects have been found for alpha-naphthylamine:

Neoplasm TDLO,	mouse	subcutaneous	25 mg/kg
Bladder cancer TDLO,	dog	subcutaneous	400 mg/kg

F. Epidemiologic Studies

Detailed epidemiological data was not available because workers are exposed to numerous chemicals besides the primary aromatic amines, the latent period in bladder cancer is exceptionally long, and the final products offer little hazard. When no significant residue of unreacted amines remain very little danger exists due to the amines. The hazard lies in the manufacture and use of these intermediates in industry.

V. Standards

Cyclohexylamine

U.S.A.	ACGIH,	TLV (air)	40 mg/cu m (skin)
U.S.S.R.,		TWA (air)	1 mg/cu m
Rumania,		TWA (air)	50 mg/cu m

Toluidine

U.S.A.	ACGIH	TLV (air)	5 ppm (skin)
	OSHA	TWA (air)	5 ppm (skin)
Bulgaria,		TWA (air)	3 mg/cu m
Czechoslovakia,		TWA (air)	5 mg/cu m
Poland,		TWA (air)	5 mg/cu m
Rumania,		TWA (air)	3 mg/cu m (skin)
U.S.S.R.,		TWA (air)	50 mg/cu m
Yugoslavia,		TWA (air)	22 mg/cu m

Phenylenediamine

U.S.A.,	ACGIH	TLV (air)	0.1 mg/cu m (skin)

VI. Environmental

All the primary aromatic amines are very reactive with oxidizing materials. They are combustible and upon decomposition emit highly toxic fumes of aniline and oxides of nitrogen. The primary aromatic amines are readily absorbed through the skin because they are fat-soluble. Because of this the salts of these compounds are used since their physical properties reduce the risk of skin absorption and inhalation, not because they are less toxic. Under shipping regulations (ICC, CG, IATA) they carry the "Poison Label". Cyclohexylamine and Alpha-naphthylamine have aquatic toxicity ratings:

Cyclohexylamine: TLm96: 1000-100 ppm
Alpha-naphthylamine: TLm96: 10-1 ppm

VII. Potential Exposure Estimates from the National Occupational Hazard Survey are:

Aliphatic, Aromatic, unclassified amines: 2,600,000
Aromatic, unclassified amines: 60,000

VIII. BIBLIOGRAPHY

1. Kirk and Othmer (eds): Encyclopedia of Chemical Technology, 2nd ed. New York, Interscience, 1966.

2. Patty, F.A. (ed): Industrial Hygiene and Toxicology, 2nd ed. New York, Interscience, 1966.

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16. ACGIH: TLV, 1976.

SECONDARY AROMATIC AMINES

I. Description

The secondary aromatic amines are defined as a primary aromatic amine where at least one hydrogen of the amino ($-NH_2$) group is substituted. Usually this substitution is by either an alkyl or aryl group.

This group of aromatic amines exhibits physio chemical properties similar to the primary aromatic amines. When compared to the aliphatic amines they share more similarities than differences. They are also rather weak bases when compared to ammonia or the aliphatic amines. They exist as high boiling oily liquids or crystalline solids. Normally they are colorless but are most commonly encountered as discolored due to their high reactivity to oxidation by light or air. They are soluble in organic solvents, fat-soluble and not soluble in water. As aromatics they exhibit a low vapor pressure, slightly moderate volatile, and a characteristic aniline odor. These compounds occur very rarely but are easily synthesized.

From a review of manufacturing processes and production data, the following secondary aromatic amines are listed below to be industrially important. Those which are being reviewed by NIOSH in "Criteria Documents" have been excluded.

	CAS Number	MW
Methylamine	000100618	107.17
2-Ethylamine	000578541	121.2
N-Butylaniline	001126789	149.23
N-Methyl-o-tolindine (p.m)		
N-Phenyl-alpha-nophthylamine	000090302	219.30
N-Phenyl-beta-nophthylamine	000135886	219.30
N-Methyl-alpha-naphthylamine		157.23
Diphenylamine	000122394	169.24

II. Production

A. Manufacturing: Industrially secondary aromatic amines are made from primary aromatic amines. The most widely used primary aromatic amine used is aniline. Through alkylation aniline is converted into most any secondary aromatic amine. Also during production of secondary aromatic amines care must be taken to suppress tertiary amine formation. This is done by carrying out the reaction under pressure at 30-60 psi with hydrogen.

B. Production: Listed below are secondary aromatic amines with the number of manufacturing companies and the number of companies distributing each compound.

	Manufacturer	Distributing
Methylaniline	2	2
2-Ethylaniline	4	13
N-Butylaniline	1	13
N-Methyl-o-toluidine (p.m)	1	8
N-Ethyl-o-toluidine (p.m)	1	9
N-Phenyl-alpha-naphthylamine	3	15
N-Phenyl-beta-naphthylamine	3	20
N-Methyl-alpha-naphthylamine	(not available)	4
Diphenylamine	6	24

Production figures are listed below for the secondary aromatic amines. Because they are powerful activators and direct electrophilic substitution in the ortho and para position they are used as the primary aromatic compounds in organic synthesis as intermediates.

	Million pounds	Year
2-Ethylaniline	5	1973
N-Phenyl-beta naphthylanine	3 rubber antioxidant	1974
Diphenylamine	40	1974

III. Uses

Secondary aromatic amines are used heavily as intermediates in organic synthesis. Some of these intermediates are in dye stuffs, pesticides, pharmaceuticals, and antioxidants. Other industrial uses are as rubber antioxidants, lubricants, cosmetic antioxidants, rubber accelerators, solid rocket propellants and analytical chemicals to test for nitrites. They have been used to stabilize nitrocellulose explosives and celluloid.

IV. Toxicity Information

A. Target Organs: Secondary aromatic amines effect the eyes, mucous membranes, respiratory tract, skin, bladder, kidney, liver, and CNS.

B. LD50 Values:

Methylaniline

Cat	IV	(LDL0)	24 mg/kg
Rabbit	Oral	(LDL0)	280 mg/kg
Rabbit	IV	(LDL0)	24 mg/kg
Guiena pig	Oral	(LDL0)	1200 mg/kg
Guiena pig	Subcut	(LDL0)	1200 mg/kg

2-Ethylaniline

Rat	Oral		1260 mg/kg

N-Butylaniline

Rat	Oral		1260 mg/kg

N-Phenyl-alpha-naphthylamine

Rat	Oral		1625 mg/kg
Mouse	Oral		1231 mg/kg

N-Phenyl-beta-naphthylamine

Mouse	Oral		1450 mg/kg

N-Methyl-alpha-naphthylamine

Rat	Oral		1410 mg/kg

Diphenylamine

Rat	Oral	(LDLO)	3000 mg/kg
Mouse	IP		250 mg/kg

C. Acute/subchronic effects:

The toxicity of the secondary aromatic amines is similar to that exhibited by the primary aromatic amines. They too are characterized by the ability to produce methemoglobin in man. The typical symptoms of poisoning are cyanosis; bluish discoloration of extremities; headache; anoxia; weakness; and dizziness. Prolonged exposure produces convulsions, psychic disturbances and depressed CNS which may cause permanent injury or death.

The secondary aromatic amines upon contact with the eyes, skin, or respiratory produce irritation. Contact with the secondary aromatic amines over a prolonged period leads to burning or blistering and dermatitis. As the primary aromatic amines they are an allergens, sensitizing to exposure. Methylaniline and 2-ethylaniline are good examples of this sensitizing effect.

Some of these, as with the primary aromatic amines, produce a transient hematuria. N-methyl-toluidine acts primarily as a liver poison and secondarily on the blood. Other aromatic amines which are diamines have potent hepatotoxic effects in experimental animals but liver damage has not been reported in the industrial environment.

The secondary aromatic amines exert great biological activity at low levels of exposure. They are absorbed through the skin or inhaled as dust, fume or vapor.

D. Long term effects:

Prolonged exposure over a period of time has been noted to produce nervous disorders, nephritis, anemia, and bladder cancer. Those which have produced bladder cancer are diphenylanine and N-phenyl-beta-n phthylanine. There are others which in experimental animals have produced neoplasms but human exposure and morbidity studies are lacking. Bladder cancer in the secondary aromatic amines is also characterized by a latent period.

E. Carcinogenicity, Mutagenicity, Teratogenicity, and Other Effects on Reproduction

In Methylaniline neoplastic effects have been observed in experimental animals but no case of human bladder cancer has been found:

Neoplasm	TD_{Lo}	Mouse	Oral	380 mg/kg (28 weeks)

N-Phenyl-beta-naphthylamine has been linked to bladder cancer but conclusive morbidity studies are lacking. It is currently being tested by NCI for carcinogenicity by standard bioassy protocol as of April 1976. Listed below are carcinogen city data:

Neoplams	TD_{Lo}	Mouse	Subcutaneous	464 mg/kg (78 weeks)
Carcinogenic Effect	TD_{Lo}	Mouse	Oral	135 mg/kg

Diphenylamine is a recognized carcinogen. Presently it is an EPA candidate for additional oncological information as of February 1976. Terarogenicity data has been found on diphenylamine:

TD_{Lo}	preg rat	Oral	7500 mg/kg

Although at this time aromatic hydrocarbons are considered very good prospects for carcinogens and much research has been done, still the active metabolite(s) and mechanisms of carcinogenic activity in the secondary aromatic amines have not been identified.

F. Epidemiologic data:

Epidemiologic data was not found on the secondary aromatic amines. Secondary aromatic amines are usually produced from primary aromatic amines which complicates the matter of morbidity studies, etc.

V. Standards

Methylaniline

USA ACGIH	TLV (air)	2ppm(skin)
OSHA	TWA (air)	2ppm(skin)
Finland	TWA (air)	2ppm(skin)
Rumania	TWA (air)	10 mg/cum (skin)
Yugoslavia	TWA (air)	9 mg/cum

Diphenylamine

USA ACGIH	TLV (air)	10 mg/m^3 (skin)

VI. Environmental

The secondary aromatic amines are reactive to oxidizing materials. They are combustible and emit highly toxic fumes of aniline and nitrogen

compounds upon decomposition. Although they are almost as toxic as the primary aromatic amines they do not produce the hazards of the primary aromatic amines. The secondary aromatic amines are not as volatile as the primary aromatic amines, and due to their structure they are not absorbed through the skin and lungs as readily as the primary aromatic amines. The secondary aromatic amines offer no problems in the final products unless some unreacted amines are left as impurities. Under shipping regulations (ICC, CG, IATA) they carry the "Poison Label."

VII. Potential exposure estimates from the National Occupational Hazard Survey are:

Aliphatic, Aromatic, unclassified amines: 2,600,000
Aromatic, unclassified amines: 60,000

VIII. Bibliography

1. Kirk and Othmer (eds): Encyclopedia of Chemical Technology, 2nd ed. New York, Interscience, 1966

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17. ACGIH: TLV, 1976

TERTIARY AROMATIC AMINES

I. Description

The tertiary aromatic amines are defined as primary aromatic amines where boath hydrogens of the amino ($-NH_2$) group are substituted. Usually this substitution is either alkyl or aryl or both.

The tertiary aromatic amines exhibit physiochemical characteristics very similar to the primary and secondary aromatic amines. When compared to the aliphatic amines they share more similarities than differences. They are weak bases as compared to ammonia and the aliphatic amines. The tertiary aromatic amines are high boiling oily liquids or crystalline solids. Normally, they are colorless but are encountered commonly as discolored due to their reactivity oxidation by light or air. They are fat-soluble, soluble in organic solvents, and not soluble in water. As aromatics they exhibit a low vapor pressure, are slightly volatile and have a characteristic aniline odor. These compounds occur very rarely but are easily synthesized.

A review of manufacturing processes and production data has shown the tertiary aromatic amines listed below to be industrially important. Those tertiary aromatic amines which are being reviewed by NIOSH for "Criteria Documents" have been excluded.

	CAS NUMBER	MW
N,N-Dimethyl-o-toluidine	000609723	135.23
Dimethyl-alpha-naphthylamine	000086566	171.2
Acridine	000260946	179.2
Hexomethylenetetramine	000100970	140.2
N,N-Dimethyloniline	000121697	121.2

II. Production

A. Manufacturing

The tertiary aromatic amines are made from both primary and secondary aromatic amines. Thorough alkylation is the easiest method for the production of tertiary aromatic amines.

Listed below are tertiary aromatic amines with the number of manufacturing companies and the number of companies distributing each compound.

	Manufacture	Distribution
N,N-Dimethylaniline	4	26
Acridine	*	13
Dimethyl-alpha-naphthylamine	*	8
N,N-Dimethyl-o-toluidine	2	2
Hexamethylenetetramine	6	25

* Not available in literature

Production figures are listed below for tertiary aromatic amines.

	Million Pounds	Year
N,N-Dimethylaniline	19.5	1974
Hexamethylenetetramine	135	1975

III. Uses

Tertiary aromatic amines are important intermediates for organic synthesis. Some of their uses are as rubber vulcanizers, campstove fuel tablets, resin manufacture, urinary antiseptic, manufacture of the explosive R.D.X. and the manufacture of dyes and pigments.

IV. Toxicity Information

A. Target Organs

Tertiary aromatic amines as in primary and secondary aromatic amines effect the eyes, mucous membranes, respiratory tract, skin, bladder, kidney, CNS and liver.

B. LD50 Values

N,N-Dimethylaniline

Rabbit	skin	1770 ms/kg
Hamster	oral (LDLo)	50 ms/kg
Rat	oral (LDLo)	1410 ms/kg

Hexamethylenetetramine

Rat	subcut	200 mg/kg
Rat	iv	9200 mg/kg
Mouse	subcut (LDLo)	200 mg/kg
Mouse	ip (LDLo)	512 mg/kg
Mouse	subcut (LDLo)	450 mg/kg
Guinea pig	subcut (LDLo)	300 mg/kg

Dimethyl-alpha-Naphthylamine

Mouse	ip (LDLo)	75 mg/kg
Rat	oral (LDLo)	500 mg/kg

N,N-Dimethyl-o-toluidine

Rat	oral (LDLo)	500 mg/kg

Acridine

Rat	oral	2000 mg/kg
Mouse	oral	500 mg/kg
Mouse	subcut	400 mg/kg
Dog	iv	90 mg/kg
Rabbit	iv	100 mg/kg

C. Acute/Subchronic effects

Tertiary aromatic amines are not as toxic as the secondary and primary aromatic amines. They are methemoglobin formers as are the primary and secondary aromatic amines. Their effect is not as strong and in some this characteristic has been only demonstrated "in vitro." They also are absorbed by the skin since they are fat-soluble. These tertiary aromatic amines at low dosages also exhibit strong biological effects. Thus absorption may be through the skin, inhaled as dust, fume, or vapor, or by ingestion. Symptoms are cyanosis, headache, nausea, anoxia and weakness. Prolonged exposure may produce convulsions, psychic disturbances, and CNS depression which is reversible when exposure ceases. Exposure also can cause dermatitis and skin irritation on contact. The tertiary aromatic amines are allergens as are the primary and secondary aromatic amines.

D. Long term effects

Long term exposure can produce anemia and bladder irritation. Hematuria has been noted. Hexamethylenetetramine produces gastro intestinal disturbances. No reports of bladder tumor were found in the literature.

E. Carcinogenicity, Mutagenicity, Teratogenicity, and other effects on reproduction :

No carcinogenic effects were found for the tertiary aromatic amines except that hexamethylene-tetramine has produced neoplasms in animal experiments: TD_{Lo} rat subcutaneous 144 gm/kg (72 weeks).

Available data indicate that the human morbidity and bladder cancer data are non-existant. Also no reports on mutagenicity, carcinogenicity, teratogenicity, or effects on reproduction that address the tertiary aromatic amines were found.

F. Epidemiologic studies

No epidemiologic studies were located.

V Standards

N, N-Dimethylaniline

U.S.A.	ACGIH	TLV (air)	5ppm (skin)
U.S.A.	OSHA	TWA (air)	5ppm (skin)

VI Environmental Data

The tertiary aromatic amines are combustible and as the secondary and primary aromatic amines emit highly toxic fumes of aniline and nitrogen compounds with decomposition. They also react with oxidizing material. Although they are toxic their hazard to industrial workers is reduced because they are not absorbed as readily through the skin as the primary and secondary aromatic amines. They also are not as volatile as the other aromatic amines. Their danger lies in the manufacture and use of the

intermediates in organic synthesis since the final products show no toxic effect unless unreacted amines are left as residues.

VII Potential Exposure Estimates from National Occupational Hazard Survey

Aliphatic, Aromatic, unclassified amines: 2,600,000

Aromatic, unclassified amines: 60,000

VIII. Biography

1. Kirk and Othmer (eds): Encyclopedia of Chemical Technology, 2nd ed., New York, Interscience, 1966

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15. Boston: Allyn and Bacon, Inc.

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17. ACGIH: TLV, 1976

PRIMARY ALIPHATIC AMINES

I. Description

These compounds are formed when one of the hydrogen atoms in ammonia has been substituted by a univalent hydrocarbon radical. The general structure is $-NH_2$. The lower aliphatic amines are gases like ammonia and are freely soluble in water. All are basic in solution and form salts. The salts are odorless, non-volatile solids freely soluble in water. A review of production and consumption data has shown the following to be industrially important primary aliphatic amines:

Hexamethylenediamine
Methylamine
Ethylamine
N-Butylamine
N-Propylamine
Allylamine
Sec-Butylamine
1-Decanamine
Dodecylamine
Hexadecylamine
Octadecylamine
Tetradecylamine
Octylamine

II. Production

Aliphatic amines have extensive use as intermediates in the chemical industry. There are four general methods of preparing amines, the specific method used depending on the amine desired, reactants available and plant economies. Briefly they are:

1. Amination of alcohol with ammonia in the presence of dehydrating catalysts

2. Amination of alcohol with ammonia in the presence of hydrogen and a hydrogenation catalyst

3. Reduction amination of aldehydes and ketones and,

4. Addition of hydrogen cyanide to branched olefins.

In 1974, 1,390,962 thousand pounds of total amines were produced in the United States of which 28,358 were butylamines, 54,677 methylamines, 3,607 propylamines and 46,232 ethylamines. Pennwalt Corporation, Air Products and Chemicals, Inc., Virginia Chemicals, Inc., and E.I. duPont de Nemours and Co., Inc. are the principal producers of primary aliphatic amines.

III. Uses

Aliphatic amines have extensive use as intermediates in the chemical industry for a number of purposes including pharmaceutical and dyestuff manufacture, rubber products, ion-exchange resins and corrosion inhibitors.

IV. Toxicity information

A. Target organs: Eyes and respiratory tract.

B. LD50 Values:

Methylamine

Mouse - subcutaneous, LDLO 2500 mg/kg
Frog - subcutaneous, LDLO 2000 mg/kg

Ethylamine

Rat - inhalation, LCLO 3000 ppm/4H
- oral, LDLO 400 mg/kg
Rabbit - skin, LD50 390 mg/kg

N-Propylamine

Rat - inhalation, LC50 2310 ppm/4H
- oral, LDLO 570 mg/kg
Rabbit - skin, LD50 560 mg/kg

N-Butylamine

Rat - oral, 500 mg/kg
- inhalation LCLO 4000 ppm/4H
Guinea Pig - skin, 500 mg/kg

Sec-Butylamine

Rat - oral, 380 mg/kg

Allylamine

Man - inhalation TCLO 5 ppm/5 min
Rat - oral, 106 mg/kg
- inhalation, 286 ppm/4H
Mouse - oral, 57 mg/kg
- ip LD50 49 mg/kg

1-Decanamine

Rat - oral 250 mg/kg
Rabbit - skin, 350 mg/kg

Dodecylamine

Rat - oral, 1960 mg/kg
Mouse - ip, 50 mg/kg

1-Hexadecanamine

Mouse - ip, 200 mg/kg

Octadecylamine

Mouse - ip, 250 mg/kg

C. Acute/subchronic effects:

Since aliphatic amines form strong alkaline solutions they can be dangerous if splashed in the eye or if allowed to contaminate the skin. They can cause irritation and severe burns. Irritation of the respiratory tract was also observed.

D. Long-term effects

A sensitization type of dermatitis was found after exposure to certain amines used in resin manufacture. Symptoms include hivelike swelling of the eyes, face and neck. Sensitization appears to be permanent and once sensitized a minimal exposure can cause symptoms. Gyocardial, vascular, and muscular lesions have been produced in animals exposed to allylamines.

Organic damage to the CNS in animals

N-Butylamine

Eye and/or Respiratory irritant

Methylamine
Ethylamine
N-propylamine
N-butylamine
Allylamine
Hexamethylenediamine

No apparent major toxic effects

Octylamine
Tetradecylamine
Hexadecylamine
Octadecylamine
1-decanamine
Dodecylamine

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction

No reports concerning this area have been found in the literature searched for primary aliphatic amines. Further research is recommended.

F. Epidemiologic studies

None were found.

V. Standards

A TLV of 10 ppm has been set for methylamine and ethylamine (ACGIH, 1976). For butylamine a TLV (skin ceiling) has been set at 5 ppm (ACGIH, 1976).

VI. Environmental data

Concentrations of primary aliphatic amines in the work place environment range from 12-18 mg/cum, the major effect being irritation of the eyes and respiratory tract, the inhalation of dust or vapor should be avoided.

VIII. Potential Exposure Estimates from the National Occupational Hazard Survey

Aliphatic, Acomatic, Amines, Unclassified - 2,600,000
Primary Aiiphatic Amines - 30,000
Methylamine - less than 1,000
Butylamine - less than 1,000
Propylamine - less than 1,000
Ethylamine - less than 5,000
Diaminopropane - less than 5,000
Diamines - 25,000

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SECONDARY ALIPHATIC AMINES

I. Description

These compounds have the general structure $\begin{matrix} R \\ R \end{matrix}\!\!>\!\!NH$ and the general formula R_2NH. A review of production and consumption data and other pertinent literature has shown the following chemicals to be of industrial significance.

Dimethylamine	1-Propanamine
Diethylamine	Dioctylamine
Dicyclohexylamine	Pyrrolidine
Dibutylamine	Didodecylamine
Diallylamine	Ditetradecylamine
Amylamine	Dihexadecylamine
Dipropylamine	Dioctadecylamine

Most of these chemicals are liquids at ambient temperatures and are miscible in water and organic solvents. All are basic in solution and form salts. The salts are odorless, non-volatile solids freely soluble in water. As they form strong alkaline solutions, they can be hazardous if splashed in the eye or if permitted to contact the skin. They are flammable and consequently pose a moderate fire risk.

II. Production

A. General methods of amine preparation are discussed under primary aliphatic amines (see Production). Most of the secondary amines are prepared by amination of alcohols with ammonia in the presence of dehydrating catalysts. In 1974, production of dimethylamines was 116,811 thousand pounds, 12,067 thousand pounds of diethylamine, 24,496 thousand pounds of 1-propanamine and 3.8 million pounds of dibutylamine.

B. Commercial Solvents Corp., Pennsalt Chemicals Corp., Union Carbide Chemicals Co., General Mills Chemical Division and E.I. duPont de Nemours and Co., Incorporated are the principal producers of secondary aliphatic amines.

III. Uses

Secondary aliphatic amines find wide usage in rubber chemicals, textile chemicals, petroleum chemicals and in electroplating. They are also used as solvents, dyes, resins, pesticides and flotation agents.

IV. Toxicity Information

A. Target organs: respiratory organs, olfactory senses.

B. LD50, LDLo and LC50 Values:

Dimethylamine	Rat	Oral	698 mg/kg	LD50
	Mouse	Oral	316 mg/kg	LD50
	Rabbit	Oral	240 mg/kg	LD50
	Guinea Pig	Oral	240 mg/kg	LD50

Diethylamine	Rat	Oral	540 mg/kg	LD50
		Inhalation	4000 ppm/4H	LC50
	Mouse	Oral	659 mg/kg	LD50
	Rabbit	Skin	820 mg/kg	LD50
1-Propanamine	Rat	Oral	930 mg/kg	LD50
		Inhalation	1000 ppm/4H	LCLo
	Rabbit	Skin	1250 mg/kg	LD50
Dibutylamine	Rat	Oral	550 mg/kg	LD50
		Inhalation	500 ppm	LCLo
		Subcutaneous	450 mg/kg	LDLo
	Rabbit	Oral	950 mg/kg	LDLo
		Skin	1010 mg/kg	LD50
		Parenteral	750 mg/kg	LDLo
Di-n-amylamine	Rat	Oral	270 mg/kg	LD50
		Inhalation	63 ppm/4H	LCLo
	Rabbit	Skin	35 mg/kg	LDLo
Diallylamine	Man	Inhalation	5 ppm/5M	TCLo
	Rat	Oral	650 mg/kg	LD50
		Inhalation	2000 ppm/4H	LCLo
	Mouse	Oral	516 mg/kg	LD50
		ip	187 mg/kg	LD50
	Rabbit	Skin	356 mg/kg	LD50
Dioctylamine	Mouse	ip	4 mg/kg	LDLo
Pyrrolidine	Rat	Oral	300 mg/kg	LD50
	Mouse	Inhalation	1300 mg/m3/2H	LC50
Dicyclohexylamine	Rat	Oral	373 mg/kg	LD50
	Mouse	Oral	500 mg/kg	LDLo
		Subcutaneous	2400 mg/kg/48WC	TDLo

C. Acute/Subchronic effects:

The amines are well absorbed from the gut and respiratory tract and dimethylamine is a normal constituent of mammalian and human urine. From the industrial point of view, the most important action of the amines is their strong local irritation produced by contact with liquids, solutions or vapors. Tracheitis, bronchitis, pneumonitis and pulmonary edema result from single exposures at near lethal concentrations and repeated exposures at sublethal concentrations. Deep necrosis of the skin will most often result from a single application of nearly all the amines. A drop applied to a rabbit's eye will result in severe corneal damage or complete destruction of the eye.

Exposure to dimethylamine is found to cause olfactory fatigue and brief exposures to 20-100 ppm produce transient eye, nose, and throat irritation. Di-n-propylamine causes severe injury to the rabbit eye and guinea pig skin. Symptoms of light headedness, drowsiness, anxiety and apprehension, nausea and death appear early in rabbits after injections of 0.5 g/kg of dicyclohexylamine. Doses of 0.25 g/kg are just sublethal and cause convulsions, temporary paralysis and act as a general skin irritant.

D. Long-term effects:

Recorded effects in man are mostly related to the local action of the amines. Exposure to the vapor of volatile amines produces eye irritation, conjunctivitis and corneal edema. Irritation of the mucous membranes of the nose and throat as well as lung irritation result from inhalation of the amines.

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction:

No reports addressing this subject area have been located. Further research in this important area is suggested.

F. Epidemiologic studies:

None found.

V. Standards

ACGIH (1976) for Dimethylamine: 10 ppm

ACGIH (1976) for Diethylamine: 25 ppm

VI. Environmental Data

As the concentrated vapors of these amines cause irritation of the respiratory tract, inhalation of these amines should be avoided. Complete, vaporproof eye protection must be worn as appropriate to prevent contact with the amines.

VII. Potential Exposure Estimates from National Occupational Hazard Survey

Aliphatic, Aromatic, unclassified amines	-	2,600,000
n-Dibutylamine	-	1,500,000
Dipropylamine	-	less than 5,000
Diethylamine	-	75,000
Dimethylamine	-	50,000
Dicyclohexylamine	-	less than 5,000

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1973. Hazardous Chemicals Data, National Fire Protection Association

TERTIARY ALIPHATIC AMINES

I. Description

These compounds have the general structure $\begin{matrix} R \\ R \end{matrix}\!\!>\!N\text{-}R$ and the general formula R_3N. A review of production and consumption data and other pertinent literature has shown the following chemicals to be of industrial significance.

Trimethylamine
Triethylamine
Tributylamine
Triamylamine
Tripropylamine
Triallylamine
Trioctylamine
Tridodecylamine

All of the alkylamines are basic when in solution and all form salts. The salts are odorless, non-volatile solid which are freely soluble in water. With the exception of trimethylamine, all are liquids under ambient conditions and are soluble in water and common organic solvents. Trimethylamine is a gas at ordinary temperature and pressure, becoming a colorless liquid when cooled or compressed.

II. Production

General methods of amine preparation are discussed under primary aliphatic amines (see Production). The tertiary amines are generally prepared by amination of alcohols with ammonia in the presence of dehydrating catalysts or from the alkyl chlorides with ammonia under heat and pressure. In 1974, 28,711 thousand pounds of trimethylamine was produced; 1,500 tons of triethylamine was produced in 1962, and 9.6 million pounds in 1971. One hundred tons of tributylamine were produced in 1962 and 10 tons of triamylamines were produced while less than 10 tons of tripropylamine and triallylamine were manufactured.

Air Products and Chemicals, Inc., Virginia Chemicals, Inc., Pennwalt Corp., and General Mills, Inc., are some of the principal producers of tertiary aliphatic amines.

III. Uses

Liquid amines are good solvents for many inorganic and organic compounds. Methylamines have important applications in almost every field of modern technology, agriculture, and medicine as they furnish the raw materials for the synthesis of other compounds. Uses of other amines are as corrosion inhibitors, intermediates for insecticides, flotation reagents, dyestuffs, rubber accelerators and accelerator plasticizers.

IV. Toxicity Information

A. Target organs: Respiratory organs, lung, liver and kidney.

B. LD50 Values:

Trimethylamine:

Mouse - ip (LDLo) 75 mg/kg
iv 90 mg/kg
subcut (LDLo) 1,000 mg/kg
Rabbit - subcut (LDLo) 800 mg/kg
iv (LDLo) 400 mg/kg
Frog - subcut (LDLo) 2,000 mg/kg
Dog - skin (LDLo) 40 mg/kg

Triethylamine:

Rat - oral 460 mg/kg
inhal (LCLo) 1,000 ppm/4H
Mouse - oral 546 mg/kg
Rabbit - skin 570 mg/kg
Guinea pig - inhal (LCLo) 1,000 ppm/4H

Triallylamine:

Man - inhal (TCLo) 13 ppm/5m
Rat - oral 954 mg/kg
inhal (LCLo) 550 ppm/4H
Mouse - oral 492 mg/kg
ip 187 mg/kg
Rabbit - skin 2,250 mg/kg

Tributylamine:

Rat - oral 540 mg/kg
inhal (LCLo) 75 ppm/4H
Rabbit - skin 250 mg/kg

Trioctylamine:

Mouse - ip (LDLo) 63 mg/kg

C. Acute/Subchronic Effects:

The tertiary aliphatic amines range from a low to high toxicity effect. Trimethylamine is moderately toxic upon inhalation. Triethylamine is highly toxic by ingestion and inhalation as it produces lung, liver and kidney damage at 100 ppm. It produced definite degenerative changes in the heart at 100 ppm and 50 ppm was sufficient to produce lung irritation and corneal injury. Tripropylamine is reported to have

only a low toxicity as are tributylamine and tridodecylamine. Triamylamine is listed as being toxic and an irritant.

D. Long-Term Effects:

Recorded effects of long-term exposure to man have not been found for tertiary amines. Long-term exposure to any of the vapors of the volatile amines may be a hazard since irritation of the eye and mucous membranes may result.

E. Carcinogenicity, Mutagenicity, Teratogenicity and Other Effects on Reproduction:

No report addressing this area has been located in the literature searched. Further research in this area is recommended.

F. Epidemiologic Studies:

None was found.

V. Standards

The current federal standard as well as the ACGIH (1976) TLV for Triethylamine is 25 ppm.

VI. Environmental Data

Since the concentrated vapors of these amines cause irritation of the respiratory tract and eye, inhalation should be avoided.

VII. Potential Exposure Estimates from the National Occupational Hazard Survey

Aliphatic, Aromatic, unclassified amines	1,000,000
Triethylamine - less than	5,000
Trimethylamine - less than	5,000

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PHYSICAL HAZARDS

VISIBLE LIGHT

Definition of Visible Light

Visible light is that portion of the electromagnetic spectrum which subtends the wavelength range from about 380 to 750 nanometers (nm) (1). The sun is the single most important source of light. The common sources of artificial light are incandescent tungsten filament lamps, fluorescent lamps and electroluminescent panels (1,2). Also, welding arcs are considered to be light sources for evaluation of occupational health problems (3). The luminance of light sources is measured in units of candelas/square centimeter (cd/cm^2) or footlamberts (fl) (2). Light energy is measured in units of lumen-hours (lmh), Joules (J) or kilowatt-hours (kWh) (2). The irradiance of a light source is measured in units of lumens/square foot (lm/ft^2) or footcandles (fc) (2).

Nature of Hazard

Proper illumination is very important in every occupational environment. Defective illumination may cause a feeling of discomfort, eye fatigue, a decrease in visual acuity, aggravation of eye defects, dizziness, headache and following exposure to extremely high energy levels such as are generated by the sun, even blindness (4).

After several years' exposure to low intensity light, miners have developed a condition known as "miner's nystagmus" (4,5). The symptoms generally associated with lack of light are marked loss of visual acuity, eye oscillations, fatigue and photophobia (5).

When too much light is present over the whole visual field or the distribution of light is extremely uneven, the task performance may be influenced (1). Where uneven lighting levels produce undesirable contract ratios or where an excessive number of bright light sources are in the line of sight, discomfort and disability of eyesight may result. The feeling of discomfort and eye fatigue usually results from excessive pupillary contraction and squinting. Disability usually is caused by a glare phenomenon which leads to reduced contrast of the retinal image (1,2). The intense sources of light such as the sun or welding arc may cause retinal injury, temporary or permanent blindness (5,6). Another visual stress can be due to the phenomenon of flash blindness (1). This condition has resulted from the eye being subjected to a sudden burst of high visible light energy, and the effects are startling: pain and temporary loss of visual function (6). In "epilepsy-prone" persons, there is a possibility of inducing seizures, when exposed to erratic changes in light levels (1), such as stroboscopic light.

Workers of all industries are exposed to visible light.

Safety Standards

The Illuminating Engineering Society (IES) has recommended levels of illumination for visual tasks at specific locations (2). The recommended values are the minimum levels for visual tasks, at anytime, for young adults with normal and better than 20/30 corrected vision (2). The levels consist of four types of lighting: interior, exterior, sport and transportation. A few examples of specific locations included in the IES's recommended levels of illumination are various industries, schools, hospitals, offices, residences, roadways, shipyards, sport areas, and locations of various transportations (2).

In 1975, the American Conference of Governmental Industrial Hygienists (ACGIH) published the Notice of Intent to Establish Threshold Limit Values of Light (7). The threshold limit value (TLV) refers to visible radiation in the wavelength range of 400 to 700 nm and represents conditions under which it is believed that nearly all workers may be exposed without adverse effects. The TLV for occupational exposure to light where luminances are known and exposure durations exceed 10 seconds in any eight hour workday was presented. The average luminance of objects continuously viewed shall not exceed 1 candela/square centimeter. This TLV is not recommended to be used for short exposure duration or pulsed light sources (7). In 1976, ACGIH published the Notice of Intent to Establish TLV's of Light and Near-Infrared Radiation (8). The TLV's refer to radiation in the wavelength range of 400 to 1,400 nm. When luminance of source exceeds 1 candela/square centimeter with known spectral radiance and total irradiance of the source as measured at the position of the eye of the worker, the TLV's 1) to protect against retinal thermal injury; and 2) to protect against retinal injury from chronic blue light exposure, are based on the integrated spectral radiance of the source weighted against hazard functions of burn hazard and blue light hazard, respectively (8).

In addition, the Mining Enforcement and Safety Administration of the Department of the Interior has recommended illumination requirements for workers of underground coal mines (30 CFR 75.1719). The illumination requirements are: 1) illuminaries shall be installed on each operating machine of work places which shall illuminate the face or rib coal surface which is within 10 feet of the front and the rear of the machine and the luminous intensity not less than 0.06 footlamberts; and 2) the surface brightness of floor, roof, coal and machine surfaces shall not exceed 120 footlamberts.

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ULTRASONICS

Definition of Ultrasound

Ultrasounds are sound waves with vibration frequency ranges above 20 kilohertz (kHz) which are above the range of human hearing (1). Ultrasonics can be generated and detected by peizoelectric and ferro-electric transducers (2). Ultrasound in the frequency range of 20 to 40 kHz is generally used in production industries for drilling, soldering, cleaning, plastic welding, mixing liquids and emulsification (3,4). The medical diagnostic exposure in the frequency range of 1 to 20 kHz was not considered to be potentially harmful (5). The propagation of sound waves through medium, e.g. liquid, with tremendous accelerations produced the effects of cavitation (1,3). Cavitation is the formation of bubbles or cavities in liquids, and audible noise can be produced by this process (6). The ultrasonic cavitation can cause rapid rupture of animal and plant cells and; its concept is applied in research laboratories (1). The shock waves produced by the cavitation produce highly effective scrubbing action for ultrasonic cleaning (1,3).

Nature of Hazard

Report of human physiological effects of ultrasonic exposure are limited. The subjective symptoms of the exposure are generally excessive fatigue, headache, nausea, and vomiting. However, it has been shown that these subjective effects might be due to the high sould pressure level of high-frequency audible noise produced by cavitation (6). Parrack has indicated that the possible cumulative ill effects, including subjective symptoms, may result in humans exposed to airborne ultrasonics measured 90 to 100 dB in 1/3 octave bands up to 63 kHz (6).

Parrack has reported that human exposure to ultrasonic frequencies in the range of 20 to 37 kHz at sound pressure levels of 148 to 154 dB may result in a brief loss of hearing sensitivity (7). At high frequency with sound pressure level of 165 dB, dizziness was noted due to vestibular disturbances which were caused by acoustic stimulation (8). In 1966, Parrack reported that the calculated lethal exposure is at least 180 dB for humans under exposure of ultrasound (7).

Many studies were reported concerning the effects of ultrasound on small animals. The effects on small fur-covered animals are more dramatic than those on humans. The small animals have a higher ratio of surface area to mass and have less total body mass to dissipate the heat than humans. Acton (6) warned that the biological effects of ultrasonic exposure on animals cannot be extrapolated directly to humans. Data of some animal experimental studies are

summarized as follows:

Animals	dB	kHz	Effects
Mice	144	18-20	Body temperature rise
"	150-155	30	Death
Guinea pigs	150-155	30	Death
Rats	95-130	10-54	Mild biological changes
"	144-157	1-18	Death
Rabbits	95-130	10-54	Mild biological changes
"	160-165	22.5-25	Death

From references 9 - 12

Application of Ultrasonics

Low intensity ultrasonic applications in industries consist of non-destructive testing of materials or devices, measurement of elastic properties of materials, judging livestock and inspecting quality of welds (2). The objective of this kind of application is to learn or to determine the characteristics of the media; the state of the media is not changed (3).

High intensity ultrasonic applications in industries consist of welding of plastics and metals, cleaning, homogenization or mixing materials, and machining of brittle materials (2). The objective of this kind of application is to produce effects on the media or their contents through which the ultrasonic wave propagates (3).

Extent of Exposure

According to the National Occupational Hazard Survey of the National Institute for Occupational Safety and Health, 1976, the estimated number of employees potentially exposed is 50,000 to 200,000.

Safety Standard

The American Conference of Governmental Industrial Hygienists published the Notice of Intent to Establish Threshold Limit Values of the Airborne Upper Sonic and Ultrasonic Acoustic Radiation (13). The levels for 1/3 octaves above 20 kHz are for prevention of possible hearing losses from subharmonics of these frequencies. The levels for 1/3 octaves below 20 kHz may cause subjective effects. At the 1/3 octave band of 20 kHz frequency, the permissible ultrasound exposure sound pressure level is 105 dB (13).

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VIBRATION

Definition of Vibration

Vibration is the term describing oscillatory motions which usually are generated by the mechanical systems (1,2). Vibration can be characterized in terms of frequency and intensity (1). There are two types of industrial vibrations which are of occupational health concern: whole-body and segmental vibrations, defined on the basis of the means by which the workers contact the vibrating system (3). Whole-body vibration is transmitted to the whole body mass from a supporting surface such as a tractor seat or a platform (3). Segmental vibration is transmitted to only part of the body by a vibrating object; the bulk of body mass rests on a stationary surface (3). An example of a source of segmental vibration is a hand-held power drill (3).

Nature of Hazard

Whole Body Vibration - Researchers concluded from results of short-term human and animal experimental studies that intense whole-body vibration can cause physiological, psychological and pathological effects in man (2,3). Vibration can cause a phenomenon known as "body resonance" in anatomical structures. The disturbance will occur, for example, at frequency range of 60 to 90 Hz, the eyeballs show a tendency to resonate and at frequency range of 20 to 30 Hz, the skull shows a tendency to resonate, which leads to deterioration in visual acuity (1,3). The direction of vibration, which can be applied vertically and longitudinally, and the position of the worker influence the amount as well as the frequencies of resonance for the affected body structures (2,3).

Experimental work has shown that low-frequency whole-body vibration can induce increased respiratory rate, pulmonary ventilation, and oxygen intake (4,5,6). Duffner et al (6) reported that marked hyperventilation was found in human subjects during exposure to vibration at a constant acceleration-amplitude in the frequency range of 2 to 7 Hz. Hood and coworkers found increases in heartrate cardiac output and blood pressure in human subjects exposed to whole-body vibration (7). They concluded that these effects are mainly due to the skeletal muscular contraction induced by vibration (7).

Also, some people have difficulty in maintaining a steady posture during a strong whole-body vibration at low frequencies (2). The physical discomfort and subjective awareness of posture sway can be associated with motion sickness (2,9). The common symptoms and signs of motion sickness are malaise, nausea and vomiting. The subjective and behavioral reactions of motion sickness include apathy, loss of normal appetite, sensitivity to physical discomfort and lessened motivation to do well in

In laboratory studies of the human tolerance of vertical whole-body vibration, the following findings were reported under sinusoidal vibration at the frequency range of 4 to 8 Hz: 1) physical discomfort at acceleration much above 0.1 g; 2) pain at acceleration close to 1 g (10,11).

Pathological effects of whole-body vibration are reported in animal experiments (12). Lethal and pathological effects of intense whole-body sinusoidal vibration were studied in small animals. Under intense vibration (about 15 g) in the frequency range of 5 to 50 Hz, the number of deaths in mice are frequency dependent (12). The pathological changes observed in mice which died were emorrhagic damage to the lung parenchyma and the myocardium, and gastrointestinal tract bleeding (12).

In humans, various spinal, ano-rectal and gastrointestinal ailments have been reported for chronic exposure to vehicle vibration (13, 14). In general, the riders in rough-riding vehicles are subject to moderate to severe jolting or continuous shaking at frequency range 1 to 10 Hz; vertical force may exceed 1 g at times (2). Rosegger and Rosegger have reported clinical and radiological evidence for premature degenerative spinal changes in young agriculture vehicle drivers (13).

Segmental Vibration - Intense vibration from hand-held power tools can be transmitted to the fingers, hands and arms of the operator (1,2,3). The extensive use of pneumatic drills, jackhammers and chain saws have been found to lead to a condition called "dead hand", "white fingers" or "Raynaud's syndrome". Patients with this condition complain of the numbness of fingers with loss of muscular control and insensitivity to heat, cold and pain (15). In susceptible persons, the development of this ailment seems to depend on the cumulative absorption of vibratory energy by the fingers or hands affected (2). Agate and Dart (16, 17) reported that localized vibratory effect on hands could cause pathologic changes in vascular and nerve systems.

Occupations potentially associated with exposure to vibration (3, 18, 19):

Whole-body vibration

Car and truck body manufacturing workers
Construction workers
Farm tractor drivers
Forest tractor drivers
Foundry workers
Furniture manufacturing workers
Lumber yard workers
Metal can manufacturing workers
Mining workers
Printing press operators
Railroad workers
Metal stamping operators
Textile workers
Truck drivers

Segmental vibration

Chain saw operators
Jackhammer operators
Pneumatic stripping tool operators
Pneumatic tool operators
Printing press operators
Rock drill operators
Metal stamping operators
Textile loom operators
Vibrating-lever operators

In 1972, Wasserman and associates (19) of the National Institute for Occupational Safety and Health conducted "walk-through tours" of 45 various industries where vibration might have been a part of the workplace situation. In 1974, Wasserman et al estimated that there were approximately 8 million workers exposed to industrial vibration in the United States (19). Of that number, about 6.8 million workers were exposed to whole-body vibrations and 1.2 million workers to segmental vibrations (20). This estimation was based upon their observations and job-type statistics obtained from the Department of Labor and the Department of Agriculture (19, 21).

Safety Standard

In 1974, the International Organization for Standardization (ISO) published the Guide for Evaluation of Human Exposure to Whole-body Vibration (ISO 2631-1974). The limits are prescribed for the frequency range from 1 to 80 Hz. The limits are intended to apply to situations involving people in normal health. The basic criteria for the limits are:

Preservation of Health or Safety-Exposure Limit

Preservation of Working Efficiency or Performance
-Fatigue-decreased Proficiency Boundary

Preservation of Comfort - Reduced Comfort Boundary.

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IMPACT NOISE

Definition of Impact Noise

Impact noise is usually produced by a mechanical process where collision occurs between two solids (1). Impact noise can be characterized in terms of rise time, peak sound pressure level and duration of intervals (2). The OSHA Standards Advisory Committee on Noise has suggested the definition of impulsive or impact noise, as "a sound with a rise time of not more than 35 milliseconds to peak intensity and duration of not more than 500 milliseconds" (3). The American Conference of Governmental Industrial Hygienists defines impact noise (or impulse noise) as "noise levels that involve maxima at intervals of greater than one second" (4). The examples of impact noise are, noises generated by drop-forge presses, printing presses, paper cutters, wood chippers and power hammers (5).

Nature of Hazard

The range of audible frequencies in the normal young human ear begins from about 15 to 20,000 hertz (Hz) (6). Under intense and sustained exposure of continuous noise in humans, excessive exposure can cause temporary or permanent changes in hearing sensitivity (2). Other effects of occupational noise exposures include the physical and psychological disorders, interference with speech communication and interference of task performance (2). Under impact noise exposure, hearing is affected by the noise level and duration of the exposure (7).

Impact noises and impulse noises are not the same type of noise. Impulse noise is caused by sudden pressure changes in gas (1). An example of impulse noise is gunfires. In the occupational environments, impulse noise may be created by impact sources (5).

In Switzerland, Guberan and coworkers (7) conducted a survey in the drop-forge industry on hearing loss due to industrial impact noise. Their data indicated that the higher noise level and longer exposures resulted in significant hearing loss. The subjects, 70 male workers and 61 male controls were evaluated with respect to the factors of years of employment in industry, military gunfire exposure, age, and otological abnormality. The number of impacts thus calculated was estimated to be 20,000 per 9 hour-workday. The maximum energy from the sound pressure was concentrated in the 4 octave bands with center frequencies of 120, 250, 500 and 1,000 Hz (7). The sound level values of the impacts varied between 108 and 120 dB (7).

Occupations potentially associated with exposure to impact noise are (5):

Blacksmith
Boilermakers
Construction workers
Crane operators
Electricians
Forgemen
Fork lift operators
Furnace workers
Hammer men
Mechanics
Millwrights
Polishers
Printing press operators
Riveters
Sanders
Smelter men
Sheet metal workers
Stamping press operators
Tool and die makers
Tow motor operators
Welders

According to a report written by Dym, Murry and Colliton, 1,200,431 workers are directly exposed to impact/impulse noise and 3,432,676 workers are exposed occasionally (5). These data are derived from "Census of Population of 1970" which was published by the Department of Commerce; "Hand Book of Labor Statistics of 1974" which was published by the Department of Labor; and "Employment and Earnings" which was published by the Department of Labor in 1975 (5).

Safety Standard

The American Conference of Governmental Industrial Hygienists published the Threshold Limit Values (TLV's) for impulsive or impact noise (3). The TLV's are dependent on the peak sound pressure level of the impulse or impact noise. No exposures in excess of 140 dB peak sound pressure level are permitted (3) It should be recognized that the application of the TLV will not protect all workers from the adverse effects of impulse or impact noise (3).

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INFRARED RADIATION

Definition of Infrered Radiation

Infrared is that portion of the electromagnetic spectrum from about 750 nanometers (nm) to about 1 millimeter (mm) (1). Infrared radiation is given off by all "heated" bodies such as the sun, an electric light bulb, and incandescent lamps (2,3). In industries, near-infrared energy of the wavelength range of 770 to 1,400 nm is commonly used (3). The tungsten filament quartz lamps, alloy resistor quartz tubes and rod type metal sheath heaters are commonly used for generating infrared radiation (3). The advantage of using infrared energy for drying, baking and dehydrating materials in processing industries is the short period of time involved to accomplish the tasks (3).

Nature of Hazard

The sensation of heat on skin usually provides warning of exposure of infrared radiation. Excessive radiation can cause thermal burns of the skin (4). Hardy and Muschouheim (4) reported that infrared radiation can penetrate the skin to a maximum depth of about 3 mm for wavelengths of about 1,200 nm. The heating effect on subcutaneous vascular tissue may cause systemic elevation of body temperature (1). The excessive heat may cause anorexia, cramps, and heat pyrexia, resulting from a breakdown of the body's heat regulatory mechanism (1). Infrared radiation can be absorbed by the eye lens, and the heating effect may lead to ocular pathology (1,2). Low intensity and long term exposure to this radiation can damage the lens and cornea and cause a condition known as "heat cataract" or "glass blowers' cataract" (1,2).

In processing industries, infrared radiation is used in: 1) drying paper, textiles, leather, meats, vegetables and porcelain; 2) baking of paints, varnishes, enamels, adhesives, printer's ink and other protective coatings; 3) preheating of thermoplastic materials for forming and tacking operations; 4) heating of metal parts for shrink fit assembly, forming, thermal aging, brazing and conditioning surfaces; and 5) spot heating for desired objectives (2,3).

Occupations potentially associated with exposure to infrared radiation are (3,5,6):

- Automobile body manufacturing workers
- Bakers
- Blacksmith
- Blast furnace workers
- Chemists
- Cooks
- Firemen, stationary
- Foundry workers
- Furniture workers
- Glass blowers
- Kiln oven workers
- Solderers
- Steelmill workers
- Welders

According to the National Occupational Hazard Survey of the National Institute for Occupational Safety and Health, 1976, the estimated number of occupational exposure workers is 50,000 to 100,000.

Safety Standard

The American Conference of Governmental Industrial Hygienists published the Notice of Intent to Establish a Threshold Limit Value for Near-infrared Radiation (7). The threshold limit value (TLV) for occupational exposure to near-infrared radiation (wavelenths of 770 to 1400 nm) for the eye apply to exposure in any eight-hour workday. With known values of spectral radiance and total irradiance of the source as measured at the position of the eye of the worker, the infrared irradiance should be limited to 10 mW/cm^2 to prevent possible delayed effects upon the lens of the eye (cataractogensis) (7).

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RADIOFREQUENCY

In recent years, the increased use of radiofrequency (RF) radiation in communications, navigational technology, radar, medical diathermy, manufacturing industries, and microwave ovens increased the concern regarding potential biological effects and health hazards of the occupationally exposed population. Investigators, mainly in the United States, the Soviet Union and Eastern European countries, have reported biologic effects in human and animals resulting from exposure of radiofrequency radiation. Various safety and health standards and protective measures for exposure to RF were established due to the differences in research approach, experimental findings and their interpretations (1).

Definition of Radiofrequency

Radiofrequency consists of the portion of the non-ionizing electromagnetic spectrum from about 0.03 megahertz (MHz) to about 300 gigahertz (GHz) (2) with wavelengths in free space of 10 kilometer (km) to 1 millimeter (mm) (2). Microwaves are generally defined to be within the frequency range of 100 MHz to 300 GHz with wavelengths in free space of 3 m to 1 mm (2,3).

Typical sources of long wavelength frequency energy (up to about 100 MHz) are electronic oscillators (3). The sources of microwave energy are klystrons, magnetrons, high frequency oscillators, and semiconductor transmitting devices (such as IMPATT diodes) (3). Radio waves propagate in a vacuum or through a number of dielectric media, i.e., air, water and biological tissue (2). The energy, when transmitted, is categorized into two discrete modes known as continuous wave and pulsed (2).

Nature of Hazard

The amount of power emitted by a radiofrequency source and the amount of energy absorbed by tissue is usually measured in watts per unit area, i.e., W/cm^2 (2). The amount of energy absorbed depends upon the electrical properties of the biological tissues, especially their dielectric constant and conductivity (5,6). Those biologic tissues which have a high water content will absorb relatively greater amounts of radiation energy than tissues with low water content, such as adipose tissue (5). The greater the frequency of the radiation, the less is its depth of penetration, i.e., frequencies in the 10 GHz range or higher are unable to penetrate beyond the skin, whereas those of less than 150 MHz frequency pass through the body with very little loss of energy (6). Intermediate frequencies penetrate to various depths, and are then able to be absorbed by internal organs (6).

The thermal effects are produced by conversion of the radiation energy into heat. Body temperature increase during exposure to radiation depends on 1) the frequency of radiation; 2) duration of exposure; 3) the intensity of field strength; 4) the thickness of skin and subcutaneous tissue; 5) the specific area of the body exposed; and 6) the thermal regulatory capacity or the efficiency of heat elimination (2,4).

Body organs which are least capable to dissipate heat are the most susceptible to microwave radiation. An organ's capability to dissipate heat chiefly depends on the rate of blood flow to the organ. Since eyes and

testicles are the organs in the body with least blood flow, they are most vulnerable to the radiation (7).

Biologic Effects on Humans and Animals

Low Radiofrequency Radiation (0.03 MHz - 100 MHz)

The biologic effects of low radiofrequency (≤30 MHz) have been reported by very few researchers (1). Bollinger conducted a short term (1 hour) biomedical study of the exposure of monkeys to low frequency radiofrequency radiation at 10.5, 19.3 and 26.6 MHz. No biological effects were observed at power densities of 100 to 200 mW/cm^2 under these experimental conditions (10). Frey reported that at very low average power, individuals exposed to radar radiation resulted in acoustic sensory response (11).

Microwave Radiation (100 MHz to 300 GHz)

Biologic Effects on Humans

Scientists at the International Symposium on Biologic Effects and Health Hazards of Microwave Radiation, Warsaw, 1973 classified the reported findings into three groups: 1)exposure to high intensities above 10 mW/cm^2 resulted in definite thermal effects and hazardous in some cases; 2) exposure to intensities to the range of 1 - 10 mW/cm^2 resulted in weak thermal effects but noticeable, and possible effects of microscopic and macroscopic nature; and 3) exposure to intensities below 1 mW/cm^2 resulted in no gross thermal effect (12).

Investigators in the Soviet Union reported studies of occupational workers exposed to microwave power densities below 10 mW/cm^2. The findings revealed the reversible functional changes in the nervous, cardiovascular and blood systems which lead to a characteristic complex of symptoms (13,14). In Rumania, a survey was reported of workers exposed to power densities of 10-100 mW/cm^2. In 31 workers studied, 70 percent of workers were found to have decreased spermatogenesis (15).

Microwaves have been shown to cause cataracts in experimental animals (16). In 1948, Hirsch and Parker noted cataracts in a microwave generator worker exposed to 1.3-3 GHz radiation at power densities exceeding 100 mW/cm^2 at times, for a total of 2 hours during the period of 3 days (17). Zaret reported selected cases of microwave cataracts in humans (18). A microwave researcher was exposed to an average power density of 500 mW/cm^2, with peaks as high as 4 W/cm^2 over a period of 3 to 4 weeks. Exposures lasted from a few seconds to 2 minutes and a cataract developed in one eye (18). From chronic low-dose exposure of microwave radiation, a radar engineer was reported to be developing cataracts after a maximum exposure of 1 mW/cm^2 over a period of 18 months. Approximately 20 years intervened between the exposure and the appearance of cataracts in this person (18).

Many investigators reviewed the reports of microwave-induced cataracts in man and some have concluded that detection of cataracts coincides only accidentally in time with the exposure to microwave, and that it might be due to other causes such as uveitis or congenital clouding (2, 17, 19).

Biologic Effects on Animals

Carpenter et al (16) reported the radiation of microwaves at 2,450 MHz pulsed or continuous waves could cause lenticular opacification in rabbits. 280 mW/cm^2 was found the single threshold exposure dose for cataract development in rabbits (16). Cumulative radiation effects on the lens of the eye were observed when the exposures were repeated at power densities from 80 mW/cm^2 to 400 mW/cm^2 for different exposure times (16).

Yagi, et al (20) reported inflammation of the bone marrow was found when the rabbits were exposed to microwave radiation of 2,450 MHz at a power density of 1.3 W/cm^2.

Ely, et al (21) conducted microwave radiation studies and found 5 mW/cm^2 at frequency of 2,880 MHz of radiation to be the threshold for testicular damage in dogs under an indefinite exposure. The investigators reported that the damage is slight and recoverable (21). However, Follis (22), in 1946, exposed the whole body of guinea pigs to 3,000 MHz of microwave radiation and did not find effects in reproduction system. Deichmann et al (23), in 1965, reported no observed effects were found in reproduction system in dogs which were exposed whole-body to 24,000 MHz of microwave radiation.

Prausnitz and Susskind (24) reported the microwave radiation effect on the hematopoietic system. When mice were exposed with 10,000 MHz at 450 mW/cm^2 for 5 minutes , values of erythocytes,leukocytes, and hemoglobin were observed at first and fifth days after the exposure (24). Hyde and Friedman (25) reported the effects from exposure of mice to 3,000 MHz with 20 mW/cm^2 and 10,000 MHz with 17, 40 or 60 mW/cm^2 up to 15 minutes. No significant effect was noted on leukocyte count or hemoglobin value after exposure. Kitsovskaya (26) exposed rats to 3000 MHz at 10 mW/cm^2 for 60 minutes per day for 216 days. The total white blood cell and lymphocyte counts decreased with an increased granulocyte count (26).

Baldwin et al (27)studied the microwave radiation effects on the controls nervous system of primates. Monkeys were exposed to 225-400 MHz, and neurologic signs of agitation, drowsiness, and abnormalities of the sensory, motor and autonomic systems were observed.

Troyanskiy and Kruglikov (28,29) studied the conditional response of rats which were exposed to high frequency microwave radiation. Prenatal rats were exposed at 50 mW/cm^2 (thermal) and at 10mW/cm^2 (nonthermal) power densities. In the offspring of exposed animals, central nervous system development was delayed (29).

Safety Standards

The current federal standard (29 CFR 1910.97) for electromagnetic radiation is based on the American National Standards Institute standard of 1966 (ANSI C95.1-1966) entitled "Safety Level of Electromagnetic Radiation with Respect to Personnel." For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 MHz to 100 GHz, the radiation protection guide is 10 mW/cm^2 as averaged over any possible 0.1-hour period, i.e. power density of 10 mW/cm^2 for periods of 0.1 hour or more; and an energy density of 1 milliwatt-hour per square centimeter (mWh/cm^2) during any 0.1 hour period. This guide applies whether the radiation is continuous or intermittent.

In 1974, the American National Standards Institute published an updated "Safety Level of Electromagnetic Radiation with Respect to Personnel" (ANSI C95.1-1974). For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 MHz to 100 GHz, the radiation protection guide is 10 mW/cm^2, and the equivalent free-space electric and magnetic field strengths are approximately 200 volts per meter root mean square (V/m RMS) and 0.5 ampere per meter root mean square (A/m RMS), respectively. For modulated fields, the power density and the squares of the field strengths are averaged over any 0.1=hour period; none of the following levels should be exceeded as averaged over any 0.1-hour period: Mean Squared Electric Field Strength-40,000 V^2/m^2; Mean Squared Magnetic Field Strength-0.25 A^2/m^2; Power Density-10 mW/cm^2; Energy Density-1 mWh/cm^2. This guide applies whether the radiation is continuous or intermittent. These recommendations are made to prevent possible harmful effects to humans resulting from exposure to electromagnetic (EM) radiation. They apply to all radiation originating from radio stations, radar equipment, and other possible sources of electromagnetic radiation such as that used for communications, radionavigation and industrial and scientific purposes. This standard is not intended to apply to the deliberate exposure of patients for medical procedures or for therapeutic purposes.

In 1976, the American Conference of Governmental Industrial Hygienists (ACGIH) published threshold limit values (TLV's) for microwave energy in the frequency range of 100 MHz to 100 GHz (31). The TLV for occupational microwave exposure, where power densities are known and exposure time is controlled is as follows: 1) for average power density levels up to but not exceeding 10 mW/cm^2, total exposure time shall be limited to an 8-hour workday (continuous exposure); 2) for average power density levels from 10 mW/cm^2 up to but not exceeding 25 mW/cm^2, total exposure time shall be limited to not more than 10 minutes for any 60 minute period during an 8-hour workday (intermittent exposure); 3) for average power density levels in excess of 25 mW/cm^2, exposure is not permissible. In addition, for repetitively pulsed sources the average power density may be calculated by multiplying the peak power density by the duty cycle. The duty cycle is equal to pulsed duration in seconds times the pulse repetition rate.

The Notice of Intended Changes for TLV's for 1976 included microwave energy (31). These TLV's refer to microwave energy in the frequency range of 300 MHz to 300 GHz. The TLV for occupational exposure to microwave energy, where power density or field intensity is known and exposure time is controlled, is as follows: 1) for exposure to continuous wave (CW) sources, the power density level shall not exceed 10 mW/cm^2 for continuous exposure, and the total exposure time should be limited to an 8-hour workday. The power density is approximately equivalent to a free electric

field strength of 200 V/m RMS and a free-space magnetic field strength of 0.5 A/m RMS; 2) exposures to CW power density levels greater than 10 mW/cm^2 are permissible up to a maximum of 25 mW/cm^2 based upon an average energy density of 1 mWh/cm^2 averaged over any 0.1-hour period; 3) for repetitively pulsed microwave sources, the average field strength or power density is calculated by multiplying the peak-pulsed value by the duty cycle. The duty cycle is equal to the pulse duration in seconds times the pulse repetition rate in Hertz. Exposure during an 8-hour workday shall not exceed the following values which are average over any 0.1-hour period: Power Density - 10 mW/cm^2; Energy Density - 1 mWh/cm^2; Mean Squared Electric Field Strength - 40,000 V^2/m^2; and Mean Squared Magnetic Field Strength - 0.25 A^2/m^2; 4) exposure is not permissible in CW or repetitively pulsed fields with an average power density in excess of 25 mW/cm^2 or approximate equivalent free-space field strengths of 200 V/m or 0.75 A/m.

In 1960, Great Britain adopted the $10mW/cm^2$ standard for radio-frequency radiation exposures for the general public as well as the military and industry (32). In Sweden, in 1961, the recommended maximum permissible intensity "within areas where personnel are occasionally to be found is $10mW/cm^2$ for all occurring frequencies" (33). The $10-mW/cm^2$ standard is also accepted in the Federal Republic of Germany and in France as the maximum safe level (34, 35).

In the USSR, the microwave personnel exposure standards, promulgated in 1959 by the USSR Ministry of Health, specify a maximum safe exposure for an unlimited period of time of 0.01 in mW/cm^2; $0.1-mW/cm^2$ exposure is permitted for a period of 2 hours in a 24-hour period; and up to 1 mW/cm^2 is permitted for 20 minutes in a 24-hour period (36).

In 1972, Poland established new microwave personnel exposure standards (37). Michaelson summarized the new Polish standards and standards of countries mentioned above in the Advisory Group for Aerospace Research and Development (AGARD) Lecture, 1975, (38) (Table I).

TABLE I

Personnel Exposure Standards for Microwaves

Maximum Permissible Power Density (mW/cm^2)	Frequency (MHz)	Country or Agency	Specifications
10	10-100,000	U.S.*	
		ANSI	1 mWh/cm^2, 24h
		NIOSH	8 h workday
	100-100,000	ACGIH	10 mW/cm^2 TLV - 8 h 10-25 mW/cm^2, 10 min/h 25 mW/cm^2 - ceiling value
	300-300,000	Army/Air Force	10-55 mW/cm^2 min = $6000/(mW/cm^2)^2$
1	300-300,000	Poland	0.2 mW/cm^2-10 mW/cm^2 (8 h - 11.5 s) (SF)**
			1.0 mW/cm^2-10 mW/cm^2 (8 h - 4.8 min) (NSF)
		USSR***	15-20 min/day
0.1		Poland	0.2 mW/cm^2, 8 h (SF) 24 h (NSF)
		USSR	2-3 h/day
0.025		Czechoslovakia	8 h (CW)
0.01		Poland	24 h (SF)
		USSR	8 h
		Czechoslovakia	8 h (pulsed)

*Also with slight modification - Canada, United Kingdom, German Federal Republic, Netherlands, France, Sweden.

**SF = stationary field (hr = $32/W/m^2$); NSF = nonstationary field (hr = $800/W/m^2$.

***MPE x 10 for exposure to movable beam or antenna.

From reference 38.

Occupations potentially associated with radiofrequency and microwave radiation exposures include the following (13,30):

Air crewmen
Drug sterilizers
Food sterilizers
Furniture veneering operators
MASER (Microwave Amplification by Stimulated Emission of Radiation) operators
Metal welders
Microwave radiation generating workers
Microwave diathermy operators
Microwave oven maintenance workers
Microwave radiation testing technicians
Plastic welders
Radar mechanics
Radar operators
Radar testing technicians
Radio transmission operators
Television transmission operators
Tempering steel workers

According to the National Occupational Hazard Survey of the National Institute of Occupational Safety and Health, 1976, the estimated employees under the occupational exposure are 10,000 to 50,000 for longwavelength radiofrequency radiation, and 5,000 to 10,000 for microwave radiation.

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LASER

Definition of Laser

A LASER (Light Amplification by Stimulated Emission of Radiation) is a device to provide a source of intense, coherent, and directional optical radiation (1). It is usually operated with an output wavelength of approximately 200 nanometers (nm) to 1 millimeter (mm) (infrared, visible and ultraviolet regions) (1). It can be operated in continuous mode, normal pulse mode, Q-switched mode, or mode-locked mode (1). The media used to generate laser radiation are: gases, liquids, crystalline materials, semiconductors and solid-state ions (2). The major applications of laser radiation in industries are in thermal processes and measurements (2).

Nature of Hazard

Biological effects of laser radiation are due to heating of the biological tissues. In humans the eye is the most susceptible organ to laser radiation. The skin may also be affected. Ocular hazards depend on the radiation absorption by the structures of the eye (3,4). The lens of the eye can focus the laser radiation of near-infrared and visible wavelength range, about 400 to 1,400 nm, onto the retina 1,4). The relative low radiation incident on the cornea can produce retinal lesion, and subsequent impairment of vision (4,5). The retinal lesions caused by laser radiation depend on: 1) the pupil size which controls the amount of light that may enter the eye, 2) the penetration properties of certain wavelenths of the radiation, 3) the retinal absorption of radiation which depends on the degree of pigmentation of the area affected, and 4) the size of the focused image on retina (1,4,5). The absorption of laser radiation of the ultraviolet wavelength range (200 to 400 nm) generally takes place at or near the surface of the cornea of the eye (3,5). Then the heating of the cornea may result due to the excessive exposure of the radiation. The iris and lens of the eye may be affected by local heating from exposure of laser radiation in the far-infrared and far-ultraviolet regions of the spectrum (3,7). The adverse thermal effects resulting from exposure of the skin to radiation in the wavelength range of 315 nm to 1 mm may vary from erythema, blistering to charring (1). The degrees of thermal effects are dependent upon the exposure dose rate, the amount of radiation irradiated, the amount of radiation absorbed, and the amount of dissipated heat from the absorption site (1).

The potential health hazards associated with laser systems are not limited to the direct beam (6). In addition, several other environmental problems must be considered, such as hazards of high-voltage electrical equipment, excessive noise levels from the laser machine, and the potentially hazardous concentrations of fumes, gases and vapors from the medium that generate the laser radiation.

The unique properties of laser radiation, such as high power density, short pulse lengths, monochromaticity and collimation, are useful in thermal processes and measurements (2). The concentrated high intensity of energy can be used in drilling, cutting, welding, and sealing hard materials in material processing industries (2,7). The coherence property of laser radiation provides an ideal source for alignment instruments and interferometers for accurate length measurements in construction industries and research fields (2). In addition to the above mentioned industrial applications, the laser radiation also has been used for treatment of retinal detachment and for treatment of

tumors in the medical field (7).

According to the National Occupational Hazard Survey of the National Institute for Occupational Safety and Health, 1976, the estimated number of employees with potential occupational exposure to laser radiation is 5,000 to 10,000.

Safety Standards

Currently, the Occupational Safety and Health Administration (OSHA) is formulating a general industry standard governing occupational exposure to laser radiation (8). This proposal is similar to the laser standards of the American National Standards Institute (ANSI Z136.1-1976), the performance standard of laser products of the Bureau of Radiological Health (9), and the safety standard of laser radiation of the U.S. Army (1). The classification scheme forming the basis for laser hazard evaluation and control is used in each of these standards (10).

In 1976, the American National Standards Institute published an American National Standard for the Safe use of Lasers (ANSI Z136.1-1976). The recommended maximum permissible levels (MPL) for ocular exposure to a laser beam is determined by the wavelength, angular substanse, size of aperture, and correction factors for certain wavelengths. The MPL levels for skin exposure to a laser beam also depends on the frequency of the laser radiation. Limit values for classifications of laser systems are established according to potential hazards.

In 1976, the American Conference of Governmental Industrial Hygienists published Threshold Limit Values (TLV's) for laser radiation (11). The TLV's are similar in concept with ANSI's laser standard (11).

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INDUSTRIAL PROCESSES

SYNTHETIC RUBBER MANUFACTURE

SIC No. 2822 Synthetic Rubber (Vulcanizable Elastomers)

Establishments primarily engaged in manufacturing synthetic rubber by polymerization or copolymerization. An elastomer for the purpose of this classification is a rubber-like material capable of vulcanization, such as copolymers of butadiene and styrene, or butadiene and acrylonitrile, polybutadienes, chloroprene rubbers, and isobutylene-isoprene copolymers.

A. Description of Process

The chemicals and materials used in the rubber manufacturing process represent an incredible array of widely varying compounds. Many of these compounds, which are also widely used in the plastics industry, have greatly varying properties and uses in the synthetic process. The most common types of commercial synthetic rubbers include: styrene-butadiene, polybutadiene, neoprene, butyl, polyisoprene, polyurethane, and nitrile rubber.

The synthetic rubber process involves the production of long chain molecules (polymers) from either like monomers (to produce homopolymers) or dissimilar monomers (to produce copolymers). The manufacturing of rubber begins by transferring these base monomers (e.g. vinyl chloride, styrene, butadiene, etc.) into a reactor vessel for polymerization. There are three basic methods of polymerization:

1. Emulsion - involves the use of starting molecules, a catalyst (persulphate or peroxide) and modifier (C12-C18 mercaptans). Polymerization takes place in a closed reactor vessel, and at the appropriate time, a stopping agent (hydroquinone or sodium dimethyl dithiocarbamate) is added. Coagulation of the emulsion is accomplished by addition of an acid (sulfuric or acetic) and sodium chloride.

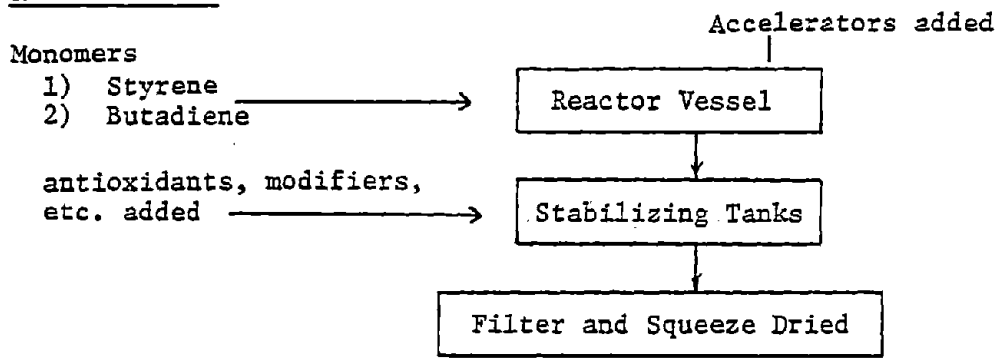
2. Solution - monomers are dissolved in a hydrocarbon solvent (hexane or benzene) and a polymerization catalyst (organoalkali metal or alkali metal) is added.

3. Condensation - two bifunctional monomers are reacted to form long chain polymers, for example, an aliphatic dihalide such as ethylene dichloride can be condensed with sodium tetrasulfide to form a polysulfide rubber.

The polymerization process, in general, is initiated by adding an acclerator (e.g. dithiocarbamates, thiazole derivatives, benzothiazyl disulfide, diphenylguanidine, etc.) to the base monomers in the reactor vessel which catalyzes the reaction by providing a source of free radicals to begin the bonding of the monomers. The emulsion is stabilized in tanks by adding stabilizers, antioxidants and activators. Some examples of

these compounds are the amino compounds, phenolics, phosphates, zinc oxide, lead monoxide, 2,2 methylenebis, etc. Different pigments, fillers, and plasticizers are added to achieve the appropriate color, flexibility, and strength of the rubber.

The general polymerization process is outlined below:



B. Hazards

The general physical hazards of handling such high volumes of chemicals include:

- splashes of chemicals on skin and especially in the eyes
- hand and arm injuries involved with handling drums, valves, and piping
- unexpected sudden release of pressures in pipelines containing chemicals
- entry into reactors where there may be high vapor concentrations
- fire and explosion hazards
- burns from contact with equipment
- falls from slipping where chemicals have been spilled on floors.

Toxicity data on the rubber processing chemicals can be evaluated in four classes: 1) monomers, 2) acclerators, 3) stabilizers, and 4) retarders.

1. Monomers

a. 1,3-Butadiene

Its physical-chemical hazards are associated with its high flammability and extreme reactivity which constitutes a dangerous

fire and explosion hazard. Experience of workers with occupational exposure to butadiene, and laboratory experiments on humans and animals indicated that its toxicity is of a low order:

- rabbits exposed to concentrations ranging from 200,000 to 250,000 ppm once a day for 15 to 21 days, showed no deleterious effects
- human volunteers breathed 8000 ppm for 8 hours with no harmful effects

ACGIH (TLV) (1975), 1,000 ppm (2,200 mg/cu m)

b. Styrene

Styrene vapors at concentrations of over 2 mg/l may cause acute poisoning with initial symptoms that include irritation of the mucous membrane and upper respiratory tract.

- rat and guinea pig studies showed 10,000 ppm was dangerous to life in 30 to 60 minutes; 2,500 ppm was dangerous to life in 8 hours
- rats exposed to 1,300 ppm styrene, 7 to 8 hours per day, 5 days per week, for 6 months had definite signs of eye and nasal irritation.

ACGIH (TLV) (1975), 100 ppm

c. Acrylonitrile

Acrylonitrile can be readily absorbed by the mucous membranes, through skin contact, or by inhalation. It has been known to possess a high degree of toxicity and to possess many of the characteristics of poisoning by the cyanide ion.

- rats exposed at an air concentration of 1.38 mg/liter (636 ppm) died after a 4 hour exposure
- rats exposed at an air concentration of 0.21 mg/liter showed slight transitory effects
- dogs were exposed at an air concentration of 0.24 mg/liter (100 ppm); three-fourths of the dogs died
- dogs exposed to an air concentration of 0.063 mg/liter showed very slight effects.

ACGIH (TLV) (1975), 20 ppm (45 mg/cu m)

2. Accelerators

a. Thiazole Derivatives

This large group of chemical derivatives has a LD50 range in mice from 2000 mg/kg to 75 mg/kg. No specific toxicity studies were available.

b. Thiram Disulfide, Bis (Dimethylthiocarbamoyl)

Thiram are relatively non-toxic substances except for the synergistic reaction of thiram and alcohol ingested together. Exposure to alcohol and thiurams together increases the acetaldehyde concentration in humans causing nausea, copious vomiting, sweating, chest pains, etc.

Rats (oral)	LD50	560 mg/kg
Mice (oral)	LD50	1350 mg/kg
Man (unknown)	LD50	780 mg/kg

U.S. Occupational Standard (air): TWA 5 mg/cu m

3. Stabilizers

a. Phenylenediamines

Systematic toxicity due to exposure to these compounds is not recognizable. However, they may cause contact dermatitis and possibly bronchial asthma. Such asthma ceases promptly with complete removal from exposure.

rats	-	oral,	LDLO	100 mg/ck
rats	-	i.p.,	LDLO	50 mg/kg
rats	-	subcut,	LDLO	170 mg/kg
dogs	-	subcut,	LDLO	100 mg/kg
man	-	unknown,	LDLO	17 mg/kg

U.S. Occupational Standard (air) for Phenol: TWA 0.1 mg/cu m (skin)

b. Phosphites

Triphenyl phosphite is a commonly used stabilizer in the phosphite group.

- studies with rats showed LD50's with oral application to be 1.6-3.2 g/kg. Tremors, diarrhea and vasodilatation by all routes was caused during this experiment
- skin and eye irritations were caused at 1.6-3.2 g/kg in a guinea pig study.

U.S. Occupational Standard (air) for Triphenyl Phosphite (TWA) , 1 mg/cu m

2027

4. Retarders

a. Benzoic Acid

Rats (skin) - LD50 1700 mg/kg

- daily intake of 4-6 gs. does not cause toxic symptoms in humans aside from slight gastric irritations

C. Extent of Exposure

Potential exposure estimates from the National Occupational Hazard Survey:

- accelerators - 500,000
- retarders - 30,000

Future

Although actual estimates for future exposures are not computed, the synthetic rubber chemical industry has increased production annually since the end of World War II. However, most modern synthetic processes are in closed systems, and exposure to these substances are limited.

D. Environmental and Epidemiological Data

A study was conducted by the Occupational Health Studies group at the University of North Carolina, Chapel Hill, N.C. which investigated a tire manufacturing plant using a hexamethylene tetramine resin (HR) system. This resin system is typical of those used in the rubber and plastics industry. Symptoms of skin and respiratory problems of both a chronic and acute nature were studied by questionnaire.

Among the three exposed groups there was no statistically significant difference in chronic respiratory and cardio-vascular symptoms. However, the reported symptoms for itch, rash, breathing irritations, cough, chest tightness, burning eyes, running nose, and a burning sensation in the heart region were significantly increased in the groups exposed to the HR compared to those groups unexposed. There was a consistency with which the HR exposed groups showed excess of reported respiratory symptoms, and a consistent association of drinking with these symptoms.

E. Illness and Injury Statistics

	Total Cases of Injury and Illness/100	Lost Workdays/ 100 Cases
Synthetic Rubber Manufacture	10.9	95.9
Mining	10.2	94.7
Contract Construction	18.3	99.8
National Average, All Occupations	10.4	54.6

F. Summary

Synthetic Rubber Manufacture (SIC No. 2822)

Process Stage	Health Hazard/Safety
monomers	flammable/respiratory effects
accelerators	low toxicity
stabilizers	possible dermatitis
retarders	low toxicity

Extent of Exposure (NIOSH Health Hazard Survey)

Number of employees - 10,000

Economic Trend - increasing rapidly since World War II

Information Gaps - it would be difficult to evaluate the synthetic rubber industry without a complete evaluation of all the major components in the polymerization process. Some component chemicals with high toxicity may be used in one of the many processes to a lesser extent than a high volume monomer or accelerator that has relatively low toxic effect levels. The chemicals with very toxic effect levels must be evaluated individually.

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PAINT AND ALLIED PRODUCTS MANUFACTURING

SIC No. 2851 Paints, Varnishes, Lacquers, Enamels, and Allied Products

These establishments are primarily engaged in manufacturing paints (in paste and ready mixed form); varnishes; lacquers; enamels and shellac; putties, wood fillers and sealers; paint and varnish removers; paint brush cleaners and allied paint products.

A. Description of Process

The manufacture of paints involves the following steps: mixing, grinding, thinning, adjusting, and filling. The additives in the paint are first mixed in a large tub with rotating blades before being fed by means of a trough into a slow speed stone mill which grinds the paste between two stones to disperse the pigments and additives and to eliminate the air pockets. This paste is then tested for viscosity, color, and other physical properties while being thinned in tanks with large rotating blades. Once the batch has passed this inpsection it is strained and poured into the appropriate size containers. This general process has been automated in certain areas using available modern technology, however the basic process remains consistent throughout the industry.

Resin based paints are usually applied to a hard surface to decorate or protect it with a solid coating. The transition from the paint's liquid phase to its solid phase requires the evaporation of a solvent, the reaction of a chemical or group of chemicals, or a combination of these processes. Paint is made up of a binder (vehicle), a pigment to provide opacity, color, and body, and a solvent to regulate the viscosity of the final paint product. Also, a variety of additives may be introduced to give the product special characteristics.

Binders: (2,150 million pounds produced in 1973)

- shellac
- linseed oil
- alkyds
- formaldehydes
- polyesters
- acrylics
- epoxies
- polyurethanes
- vinyls
- rubber derivatives
- bitumens

Pigments: (2,445 million pounds produced in 1973)

- titanium dioxide
- zinc oxide
- lithopone
- calcium carbonate
- magnesium silicate
- barium sulfate
- iron oxides
- cadium sulfide
- cadium selenide
- chromium oxide
- ferric ferrocyanide
- lead (declining use)
- mercury (declining use)
- carbon

Solvents: (4,185 million pounds produced in 1973)

Discontinued aromatic solvents:
1) benzene
2) tetrachloroethylene
3) carbon tetrachloride

Currently used solvents:

trichloroethylene	ketones
hydrocarbons	menthylated spirits
alchohols	petroleums
esters	

Additives: (225 million pounds produced in 1973)

pentachlorophenol	zinc particles
sodium salts	silica
organo lead compounds	antimony oxide
plasticizers	cadmium red
corrosion inhibitors	

Latex paint has become increasingly popular in today's paint market. The formulation of latex (synthetic resin emulsion) paints involves basically the mixing of pigment and latex. The three main types of latex polymers are based on esters of acrylic acid, polyvinyl acetate, and styrene-butadiene. Additives include pigment dispersing agents (e.g. tetrasodium pyrophosphate and soya lecithin); protective colloid thickeners (e.g. sodium polyacrylates carboxymethyl cellulose, colloidal clays, and gum arabic); coalescing agents (e.g. hexylene glycol and ethylene glycol monobutyl ether acetate); freeze-thaw additives (e.g. glycols); preservatives (e.g. copper and phenolic compounds), and PH control additives (e.g., ammonium hydroxide).

Varnishes are unpigmented resinous surface coatings, which may be used alone or as paint bases. The manufacture of resins and varnishes is by far the most complex process in paint plants, because of the large variety of raw materials and cooking formulas used. There are two categories of varnishes:

Spirit varnishes: Formed by dissolving a resin in a solvent. Lacquers are in this class, and are made of cellulose derivatives (such as cellulose acetate or nitrocellulose), resins, and plasticizers in a solvent or diluent.

Oleoresin varnishes: Solutions of both resins and oils.

Resins used in the manufacture of both groups include those as listed under "binders" above. The alkyds are by far the most widely used, followed by the vinyls. These are cooked in huge closed-system reactors, thinned, filtered, and stored.

Oils used include linseed, soybean, safflower, tall oil fatty acid, tall oil, fish oil, castor, coconut, cottonseed, lauric acid, pelargonic acid, isodecanoic acid, and tung, oiticica and dehydrated castor, to a minor extent.

Solvents include mineral spirits, VM&P naphtha, toluol, xylol, and terpenes.

The varnishes and resins may be piped to storage vessels for later use in paint manufacture, or may be packaged and sold.

B. Hazards

Some of the potential hazards that may occur as a result of the physical processes include:

- inhalation of dust during the weighing out process, the emptying of bags of dry pigment, or the accidental breakage or spillage of packages
- inhalation of hazardous vapors in manual filling of paint cans and during cleaning and repair of vessels
- skin irritation occuring from contact with synthetic resins
- noise generated by the milling machines
- fire where hazardous solvents are being employed
- the rollers, arms, and worms of the milling and mixing machines are potential injury hazards

Toxicity data can be grouped into four categories of the paint's component chemicals : a) binders; b) pigments ; c) solvents ; d) additives.

a) Binders:

Turpentines

Lehman (1914) reported immediate mucous membrane irritation particularly of the eyes, and slight convulsions in cats exposed at 540 to 720 ppm for a few hours. Death resulted from a 45 to 60 minute exposure at 2,880 ppm to the turpentine vapor.

Men exposed at concentrations of 720 to 1,100 ppm complain of eye irritation, headaches, dizziness, nausea, chest pains, and visual disturbances. Albuminurea and hematuria have been reported in men exposed to turpentine vapors. There is also evidence of renal injury after several weeks' exposure to turpentine.

Long - term chronic studies have shown cats exposed at 155-180 ppm to turpentine vapors for 3.5 hr/day for 8 days showed no observable injury. In guinea pigs, prolonged exposure at 750 ppm had no adverse effects

on blood due to the exposure. Some humans, however, develop a hypersensitivity to turpentine after prolonged or repeated exposure to it.

- ACGIH (TLV) (1976) for turpentine, 100 ppm

Diethyl Phthalate

This phthalate is generally considered to have little acute or chronic toxic properties. It has produced no irritation to skin; however, when people are exposed to the heated vapor of this compound some transient irritation of the nose and throat is recorded.

- ACGIH (TLV) (1976) for diethyl phthalate, 5 mg/cu m

Aldehydes

There are three basic effects of the aldehydes:

1) primary irritation to the skin, eyes, and mucosa of the respiratory tract

2) sensitization of the mucosa of the respiratory tract

3) anesthesia

b) Pigments

Titanium Dioxide

Studies investigating the dermatologic effects of this compound showed no observable correlation. One Italian report found no significant pulmonary alterations among workmen employed in enclosed workshops with TiO_2. In the United States no reported data has been collected on the effect of TiO_2 exposure.

- ACGIH TLV (1976) for Titanium dusts, 15 mg/cu m

Chromium Oxide

Exposure of mice and rats to "mixed" chromate dust at 1 to 3 mg of CrO_3/cu m for 4 hours daily throughout the major part of their lifetime resulted in no observable cancers. However, CrO_3 has been reported in other studies to yield tumors.

- ACGIH TLV for CrO_3, 0.1 mg/cu m

c) Solvents

Thinners (Ketones)

Thinners may cause dermatitis upon contact with the skin. Ketones are less likely to present serious hazards because the vapors are

irritating to the eyes and serve as an effective warning. In general, ketones increase their toxicity, irritation, and narcotic potency with their increasing molecular weight. In liquid form, the common ketones are painful and irritating to the eyes, and prolonged or repeated exposure can cause skin to chap, rendering it susceptible to invasion by other material.

Acetone is slightly toxic, causing irritation to the eyes and upper respiratory tract when inhaled, and causing narcosis when inhaled in very high concentrations. With prolonged exposure to acetone, gastritis, weight loss, anemia, and liver enlargement can occur.

Standards

COMPOUNDS	ACGIH (TLV)
acetone	1,000 ppm
methyl ethyl ketone	200 ppm
methyl N-propyl ketone	200 ppm
methyl N-butyl ketone	100 ppm
methyl isobutyl ketone	100 ppm
ethyl butyl ketone	100 ppm

d) Additives

Antimony

Rabbits fed daily up to 150 mg/kg of Sb_2O_3 for 4 weeks showed no pathological changes. Daily inhalation of Sb_2O_3 by guinea pigs 2 to 3 hours per day of a mean dust level of 45.4 mg/cu m produced extensive pneumonitis in all the animals and fatty degeneration of the liver in most of them. The effects required exposure of 33-60 hours.

LD_{50} for Sb_2O_5:

Rat - ip, 4 g/kg

- ACGIH (TLV) 1976 for antimony and compounds, 0.75 mg/cum

C. Extent of Exposure

1. Current exposure:

Number of establishments:	1599
Number of employees, total:	65,900
Number of production workers:	32,200
Number of administrative and support personnel (by difference):	29,700

2. Future exposure - the average annual growth rate of the surface coating industry has been estimated from 1971 to 1976 to be in the range of 7-11% down from the 12% per year growth rate estimated for 1966 to 1971.

Production of latex paints will continue to grow at the expense of solvent-based, oil and alkyd paints. The growth of the acrylic latex paints is expected to come primarily as a result of air pollution legislation limiting the amount or kinds of solvent-based paints that can be used.

D. Environmental and Epidemiological Data

No epidemiological or environmental data were found in the published literature, however the National Painting and Coating Association is presently arranging for such studies to be contracted.

E. Illness and Injury Statistics

	Total Cases of Injury and Illness/100	Lost Workdays 100 Cases
Paint and Allied Products Manufacture	14	57
Mining	10.2	94.7
Contract Construction	18.3	99.8
National Average, All Occupations	10.4	54.6

F. Summary

Paint and Allied Products Manufacture (SIC No. 2851)

Extent of Exposure

Number of employees - 65,900

Economic Trend

Increasing at a rate of 7-11% each year with emphasis shifting toward latex base paints.

Information Gaps - Epidemiologic studies are necessary and are in the process of being contracted out by the National Paint and Coating Association

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TIRE MANUFACTURING

SIC No. 3011 Tires and Inner Tubes

This includes establishments primarily engaged in manufacturing pneumatic casings, inner tubes, and solid and cushion tires for all types of vehicles, airplanes, farm equipment, and children's vehicles; tiring; and camelback, and tire repair and retreading materials.

Camelback for tire retreading
Inner tubes: airplane, automobile, bicycle, motorcycle, and tractor
Pneumatic casings (rubber tires)
Tire sundries and tire repair materials, rubber
Tires, cushion or solid rubber
Tiring, continuous lengths: rubber, with or without metal core

A. Description of Process

The tire manufacturing industry uses a variety of chemical additives to produce elastomers which are appropriate for the end function of the tire. The process is begun using a widely practiced technique called masterbatching. The batch ingredients include:

1) base polymers (styrene, 1,3-butadiene)
2) accelerators (catalyze the cross-linking reaction)
3) accelerator modifiers (activators and retarders) e.g. zinc oxide, stearic acid, etc.
4) antioxidants
5) reinforcing fillers: carbon black, minerals, silica
6) processing aides (peptizers for polymers, softners, plasticizers, dispersing aides, etc.
7) coloring materials
8) blowing agents

Masterbatching is utilized to avoid weighing small quantities of powders and to facilitate the thorough mixing of ingredients.

After masterbatching, more complete mixing can be accomplished by a variety of machines. One that is widely used is the Banbury mixer, an internal mixer that consists of two horizontal rotors with nogs or protrusions, encased by a jacket. Both mixing and mastication can be achieved by the Banbury.

Although mixing is a quite necessary process, it essentially only distributes the ingredients in the polymer. The critical, complete dispersion of the fine particle fillers is ultimately accomplished with repeated milling on two-roll mills. Extrusion of any sort is accomplished on machines (extruders) that force the rubber through a die or nozzle; the pressure can be produced by a screw or by a ram.

The bonding of the rubber to nylon/cotton cord fabric to form the tire "ply-stock" is called calendering. The rubber industry usually employs a

calender with three or four rolls. Rotation of the rolls creates a "sheet" of desired thickness.

Curing or "vulcanization" is essentially heating the rubber with certain chemicals to elicit desirable properties in the finished product. A more technical description defines vulcanization as "the chemical reaction that brings about the formation of cross-links between the polymer drains."

The major type of rubber used in the United States for tire manufacturing is Styrene-butadiene (SBR). Approximately 65-70% of all SBR produced in 1973, estimated at 2,170 million pounds, was used in the tire industry. It is expected that the future growth of the Styrene-butadiene industry will be approximately 9-10% annually through 1978.

1. Vulcanization Agents
   selenium
   tellurium
   thiuram disulfides
   p-quinone dioximes
   polysulfide polymers
   alkyl phenol sulfides
   zinc oxide
   magnesium oxide
   organic peroxide

2. Accelerators of the Vulcanization Process
   aldehyde amines
   quanidines
   thiazoles
   sulphenamides
   dithiocarbamates
   thiuram sulphides
   xanthates
   morpholine
   tetramethylthiuram disulfide

The vulcanization process requires high temperature and pressure to transform a rubber which is soft, weak, and of low tensile strength to a rubber that is hard, has high revound, high vicosity, and high tensile strength.

B. Hazards

There are many physical hazards which are associated with the handling of high volumes of chemicals. Some are:

- splashes of chemicals on skin and especially in the eyes
- hand and arm injuries involved with handling drums, valves, and piping
- unexpected sudden release of pressure in pipelines containing chemicals

. entry into reactors where there may be high vapor concentrations

. fire and explosion hazards

. burns from contact with equipment

. falls from slipping where chemicals have been spilled on floors

Toxicity information on the curing agents in the tire industry can be grouped as follows:

1. Vulcanizing Agents

a. Selenium

Selenium resembles arsenic and tellurium in its physiological action. It can be aquired from inhalation of the dust, vapor, gases, and fumes of the metal or its compounds, by ingestion, and to some extent by absorption through the skin. The first signs of selenium poisoning are nervousness and fear followed by vomiting, then quietness and somnolence. Respiration may also become impaired.

Excretion of concentrations greater than 0.2 mg/liter of urine indicate potentially harmful exposures, and concentration of 0.5 mgs. or more per liter of urine warrant immediate consideration of corrective measures.

ACGIH TLV (1976) Selenium Compounds (as Se), 0.2 mg/cu m

b. Thiurams, Disulfide

Thiurams are relatively non-toxic substances except for their reaction when ingested with alcohol. Exposure to both alcohol and thiurams together increases the acetalhyde concentration in humans causing nausea, copious vomiting, sweating, chest pains, etc.

LD50
rats - oral, 560 mg/kg
mice - oral, 1350 mg/kg
man - unknown, 780 mg/kg

U.S. Occupational Standard (air) TWA, 5 mg/cu m

c. Magnesium Oxide

Examination of 95 men exposed to magnesium oxide dust revealed only slight irritation of the eyes and nose, although the Mg level in the serum of 60 percent of those examined was above the normal upper limit of 3.5 mg percent.

Experimental metal fume fever in man has been produced by exposure to excessive concentration of fresh MgO fumes.

Lowest published lethal concentration
human - inhalation, 400 mg/cu m

U.S. Occupational Standard (air) TWA, 15 mg/cu m

2. Accelerators

a. Thiazole Derivatives

This large group of chemical compounds, probably the most often used accelerators in rubber processing, has very little specific toxicity data in the published literature.

LD50 for Thiazole, 2 4 - Diamino-5-Phenyl
rat - ip, 300 mg/kg
mouse - oral, 372 mg/kg
mouse - ip, 200 mg/kg

LD50 for Thiazole, 2-amino
rat - oral, 480 mg/kg
mouse - ip, 200 mg/kg

b. Dithiocarbamates (Zinc Salts)

The soluble salts of zinc that ionize most completely, such as zinc chloride, are quite irritating and can be used as escharotics. If taken internally, the zinc salts irritate the gastric mucosa and cause vomiting. On this basis, zinc sulfate has been used as an emetic. Exposure to mists and fumes of zinc salts may give rise to irritation of the respiratory and gastrointestinal tracts.

LD50
rat - ip, 40 mg/kg
mouse - ip, 29 mg/kg
rabbit - scut TDLo, 2.5 mg/kg

ACGIH TLV (1976) for Zinc Chloride fume, 1 mg/cu m

c. Morpholine

Morpholine is moderately toxic by ingestion and inhalation. It can cause skin and respiratory tract irritation, but no chronic effects have been observed. Morpholine has also produced kidney damage in experimental animals.

All rats exposed to the saturated vapor died within 4 hours; 1 hour was the maximum time for no deaths. Exposure to 8,000 ppm for 8 hours resulted in no death for 6 of the 20 rats.

Morpholine Toxicity

Species	Dose	Route	Response
rat	1.6 g/kg	oral	LD50
guinea pig	0.9 g/kg	oral	LD50
rat	0.8 g/kg	oral	death in 19/30 injury to liver
rat	0.16 g/kg	oral	death in 18/20 milder liver and kidney injury
guinea pig	0.45 g/kg	oral	death in 16/20
guinea pig	0.09 g/kg	oral	death in 3/20
rabbit	0.9 g/kg	skin	7/7 died before 11th dose

ACGIH TLV (1975) skin, 20 ppm (70 mg/cu m)

C. Extent of Exposure

Number of establishments (total):	206
Number of employees (total):	107,500
Number of production workers:	83,100
Number of administrative and support personnel:	24,400

Future

The most significant factors facing the demand for passenger car tires in the future will be;1) the increasing preference for radial tires at the expense of bias-ply and belted-bias tires, 2) an expected limit to the gasoline supply which will cut back the average number of miles driven per automobile tire per year, and 3) a long term shift to smaller cars and the subsequent need for small automobile tires.

The indications of these factors point towards a forseeable decrease in the demand for automobile tires, and consequently a decrease in the volume of tire manufacturing.

D. Environmental and Epidemiological Data

The Registrar General (England) noted an excess of bladder tumors among rubber and chemical workers in the 1920's. Utilizing death certificate data supplemented by hospital records, occupational histories and census data, Case (Brit. J. Prev. Soc. Med. 8:3, 1954) reconstructed cohorts which defined a clear association between employment in the rubber industry and bladder tumors. Further, his data supported the hypothesis that the increased risk was associated with the use of the antioxidant naphthylamine.

Mancuso (Journal of Occupational Medicine 10:213 (1968)) has summarized other approaches to the study of the rubber industry. In a national mortality study by industry and occupation ,excessive deaths were noted for

malignancies of the intestine, respiratory tract, lymphatic and hematopoetic system and arteriosclerotic heart disease. Insurance mortality data noted a higher mortality among compounder and machine operators. In a disability study using Social Security data excessive morbidity was noted for malignant neoplasms of the respiratory system, chronic rheumatic heart disease, emphysema, and arthritis. Mancuso (Acta Union Internationale Centre le Cancer, 19:488 (1963)) summarized a series of approaches using mortality data to investigate a possible association between tumors of the Central Nervous System and employment in the rubber industry.

A principal limitation in most mortality studies is the difficulty in precisely defining the exposure variables. In most studies exposure categories were nonexistent or quite general and quantitative environmental data was not available. Also, the design must be such that sufficient numbers (deaths) will be generated to permit meaningful comparison of cause-specific rates. Clearly, prospective morbidity and mortality studies with meaningful environmental data are necessary to definitively identify and assess the health problems in the tire manufacturing industry.

E. Illness and Injury Statistics

	Total Cases of Injury and Illness/100	Lost Work-days/100
Tire Manufacturing	17	93
Mining	10.2	94.7
Contract Construction	18.3	99.8
National Average, All Occupations	10.4	54.6

F. Summary

Tire Manufacturing (SIC No. 2822)

Process Stage	Health Hazard
vulcanizing agents	potentially harmful
accelerators of vulcanization	respiratory hazards

Extent of Exposure (NIOSH Health Hazard Servey)

Number of employees - 107,500

Economic Trend - there will be a 9-10% increasing demand in the short-term outlook with a decreasing demand in the long-term perspective.

Information Gaps - Mortality studies which precisely define the exposure variables of specific compounds used in the tire manufacturing process are necessary to accurately evaluate the health hazards in this industry. Each compound suspected of toxic effects should be analyzed as a separate component with valid human epidemiological studies.

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LEATHER TANNING

SIC No. 3111 Leather Tanning and Finishing

These establishments are primarily engaged in tanning, currying, and finishing hides and skins into leather. This industry also includes leather converters, who buy hides and skins and have them processed into leather on a contract basis by others.

A. Description of Process

Being a widespread and relatively old industry that produces a large variety of products, there are great variations in scale of operation and degree of mechanization in the leather tanning industry. In addition, the type of product made determines the choice of tanning agents, procedures, and the kind of finishing required. Basic steps in leather tanning are outlined below:

Curing: Prior to tanning, hides and skins are cured for purposes of short-term preservation. In the US, this generally involves the application of dry salt or immersion of the hides in a salt brine, which may be done either at the slaughterhouse or at the tannery.

Pretanning: Operations vary according to the conditions in which the hides are received and the class of leather to be produced. Foreign hides, if not inspected at the country of origin, must be disinfected for hoof-and-mouth disease, which involves soaking in a 1:5000 solution of sodium acid fluoride. The hides are cut, stamped, and washed. If they are too dry, softening agents, such as sodium sulfide, sodium polysulfide, or soda ash are added to the soak water. Disinfectants such as bleaching powder, chlorine, and sodium fluoride may be added to inhibit putrefaction.

Liming: This loosens the hair and removes unwanted soluble proteins and fats. The hides are soaked in 10-12% hydrated lime for 5-8 days. Sulfides (e.g., sodium sulfide, sodium hydrogen sulfide), amines (e.g., dimethylamine) and cyanides may be added as accelerating agents.

Unhairing: Hair may be dissolved from the hides with sodium sulfide or may be removed mechanically by machine or by hand. Proteolytic enzymes have recently been introduced for this purpose.

Bating: Limed stock is neutralized with buffering salts, such as ammonium sulfate or chloride. These may be used in combination with a proteolytic enzyme, which modifies the collagen so that tannage is possible.

Pickling: When the hides are to be chrome tanned, they are pickled in a salt-acid mixture (commonly sodium chloride-sulfuric acid) in paddle vats or drums; 2-naphthol or p-nitrophenol may be added to prevent mold growth.

Tanning: There are two basic tanning procedures, depending on the desired end product: vegetable tanning or chrome tanning. These methods may be combined in making certain grades of leather.

Vegetable Tanning: This process is used for tanning heavier leathers. It involves the immersion of hides in progressively more acidic solution of tannin in a series of about 14 large pits over a period of around 3 weeks. Sulfuric, lactic, or other acids are used for pH control. Vegetable tannins are derived from plant material, and they vary in chemical composition, depending on their source. Each produces a leather having distinct physical and chemical properties. All natural tannins used in the US are imported. Synthetic tanning agents may be used, alone or in combination with natural tannins. Most "syntans" are condensation products of formaldehyde and naphthalenesulfonic acids, various phenols and sulfonated phenols, diaryl sulfones, urea, melamine, and dicyandiamide. Other "syntans" include styrenemaleic anhydride, aryl diisocyanates, and ligninsulfonates.

Chrome Tannage: The process most often used is the "one bath" method, in which chromium (VI) is reduced to basic chromium (III) sulfate in the tanning liquor before the hides are immersed in it. Sodium dichromate, sulfuric acid, and glucose are the most commonly used reducing agents; other compounds, including sulfur dioxide gas and wood dust are used to a limited extent.

The "two bath" method is used mainly on goat and kid skins, and is done in paddle vats. The skins are first treated in a sodium dichromate-sulfuric acid solution, then treated with sodium thiosulfate, causing reduction of the chromium (VI) to basic chromium (III) sulfate. Any remaining acid is neutrallzed by addition of an alkali, such as sodium bicarbonate. Numerous (unidentified) sulfur by-products are formed in this process.

Other tanning agents, used in specialty items, include basic zirconium sulfate, sulfonyl chloride, formaldehyde and alum, glyoxal resin, urea-melamine and styrene-maleic anhydride modified mineral tannages, and iron (used now in pilot stage; may be substituted for chrome in the future).

Post-tanning processing may include:

-splitting and shaving

-dyeing: basic, acidic, or direct dyes may be used

-fat liquoring: lubricates leather fibers; may be done simultaneously with dyeing; the solution is a mixture of raw oil (vegetable, animal, or mineral) and a soap or sulfonated oil.

-drying: 1)paste-drying: leather is covered on the grain side with a starch paste, then is spread on glass plates and slowly dried.

2)toggling: skins are stretched on a frame, then go as a group into huge drying tunnels.

-bleaching: the leather is immersed in a vat containing sodium bicarbonate, then is neutralized with sulfuric acid.

-oiling: skins are mechanically softened, then coated with oil manually. Oiling materials include sulfated oils and soaps, usually in combination

with an alkaline salt.

-oil wheeling: the leather is put into a drum and heated and rotated. Magnesium sulfate, glucose, raw oil, mineral oil, or sulfated oil are added. A disinfectant may also be added to provide mildew resistance.

-stuffing: imparts water repellency; oils, greases, and/or waxes are added to the leather, which is "drummed" at 150-160 F. Alternative processes are "burning in", in which hot dry leather is set on a table and a hot (195 F) molten grease mixture is poured on, and "hot-dipping", in which the leather is dipped into tanks of high-melting fats, waxes, or greases.

Finishing: Skins and hides are considered to be leather by this time, but from a commerical standpoint, the leather must be finished before it becomes a salable product. Finishing processes include:

-sammying: mechanical softening, whereby leather is rolled between a glass roller and a wood bed, then is stacked in piles with moist sawdust between each piece.

-pigment application: applied by spraying machine or by hand

-lacquer and resin finishes: are mixed with solvents and applied by spraying machinery.

A fairly recent innovation in the application of surface finishes is the use of finishing machines, where the leather is carried on conveyor belts under a series of finish-sprayers, then passes under infrared lights for quick drying.

B. Hazards

-handling of raw hides and skins; infection with pathogenic organisms, such as anthrax, through abrasion, inhalation, or ingestion

-slippery, wet, and greasy floors

-unguarded pits and vats

-safety hazards related to operating various machinery, including revolving drums, in-running rollers, and knives

-dusts of vegetable tannins, lime, wood sawdust and leather dust, which may lead to chronic bronchitis

-cleaning of storage vats; hydrogen sulfide or carbon dioxide are potentially hazardous decomposition products.

-mistaken mixture of wrong solutions, resulting in the evolution of toxic gases

-exposure to the various leather processing chemicals, including:

Sodium acid fluoride*

Chlorine*

Sodium fluoride*

Sodium sulfides: unstable; on contact with air, alkaline solutions are slowly converted to solutions of sodium thiosulfate and sodium hydroxide; exposure of the crystals to air produces hydrogen sulfide; when heated to decomposition, emit highly toxic fumes or sulfur oxides; cause skin and mucous membrane irritation.

Amines: most reported effects are those due to local action, including lung and mucous membrane irritation from vapor exposure, skin and eye burns from liquids, and sensitization reactions; reported systemic effects following inhalation include headache, nausea, faintness, anxiety.

Cyanides*

Proteolytic enzymes: dermal, inhalation and eye effects.

Ammonium sulfate: low toxicity.

Ammonium chloride: large oral doses cause nausea, vomiting, acidosis.

Sulfuric acid*

2-naphthol: local action may produce peeling of the skin, which may be followed by persistent pigmentation; large oral quantities may cause nephritis, lens opacity, vomiting, diarrah , abdominal pain, circulatory collapse, convulsions, hemolytic anemia, death.

P-nitrophenol: methemoglobin former, but less so than aniline and mononitrobenzene; absorbed through intact skin; vapors absorbed through respiratory tract.

Tannic acid: essentially non-toxic; may cause local drying and discoloration of skin.

Lactic acid: low toxicity.

Syntans: phenols*.

formaldehyde*

naphthalenesulfuric acid: slight irritant; not a sensitizer.

urea: not a problem.

melamine: may cause dermatitis in humans; other toxicity unknown.

dicyandiamide: toxicity unknown.

Chromium compounds*

Sulfur dioxide*

Hydrogen sulfide*

C. Extent of Exposure

Establishments, total:	517
Number of employees, average:	25,700
Number of production workers, average:	22,100
Major producing states:	Massachusetts, Wisconsin, Maine, New York, New Jersey, Pennsylvania, California

D. Epidemology

There have been few epidemiologic studies conducted on leather-industry workers. One study, conducted by a shoemakers union, showed that of 300 male bladder patients (unspecified ailments), 12 were employed in various leather-working occupations. Shortcomings of this study are that it isn't specific to leather tanning and that the statistical techniques used are unclear or questionable.**

A case-control epidemiology study surveying 13 occupations and 17 cancer sites was recently published by Viadana, etal. The population consisted of 11,591 white men admitted to Roswell Park Memorial Institute in Buffalo, New York, between 1956 and 1965 on suspicion of having cancer. As each patient was counted for each different occupation he worked, the total sample size amounted to 17,714 diagnosed cancer and non-neoplastic cases. The relative risks at each cancer site for each occupation were calculated with adjustment for age, using the combined non-neoplastic patients as controls. For workers in the leather industry, elevated relative risks (all significant at the 5% level) appeared in carcinoma of the larynx (3.633 for all workers "ever exposed"; 6.896 for those exposed 5 years or more), mouth and pharynx (3.378, all workers; 3.772, those exposed 5 years or more), and bladder (6.773, all workers; 12.935, those exposed 5 years or more). After standardization for smoking history, the relative risks were still significantly increased.

*A NIOSH criteria document has been or is being prepared on this substance.

**Personal communication, Mark Boeninger, NIOSH-Cincinnati.

E. Injury and Illness Statistics

	Total Cases of Injury and Illness/100	Lost workdays/1(Cases
Leather tanning	21	132
Contract construction	18.3	99.8
Mining	10.2	94.7
National average, all occupations	10.4	54.6

F. Economic Trends

Economic trends in the leather industry vary from year to year, depending on such factors as domestic supply, demand, and prices of hides and on foreign markets. Production is expected to increase in the next few years due to consumer demand for leather articles and to process improvements.

G. Other

The Environmental Protection Agency recently contracted for an assessment of the industrially hazardous waste practices of the leather tanning and finishing industry. The study will focus on solid waste disposal practices. Prime emphasis will be on those waste substances which pose a potential health or environmental hazard. Elements of this study may be useful to NIOSH in evaluating health hazards to leather tannery workers. Also,a NIOSH pamphlet, "Good Work Practices for Tannery Workers" was published in 1976.

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DYEING AND REFINISHING TEXTILES

SIC No. 2231 Broad Woven Fabric Mills, Wool (Including
(Including Dyeing and Finishing)

These establishments are primarily engaged in weaving fabrics over 12 inches in width, wholly or chiefly by weight of wool, mohair, or similar animal fibers; those dyeing and finishing all woven wool fabrics or dyeing wool, tops, or yarn; and those shrinking and sponging wool goods for the trade.

A. Description of Process

There are three major considerations involved in the dyeing and refinishing of a piece of fabric or material. They are:

1) type of material

2) affinity of the dye for that material

3) volume of material

To select a dye properly, it is necessary to know which dyes have an affinity for the vegetable, animal, or man-made fibers. For example, some dyes used for cotton and linen may also be used for rayon, but polyesters and other synthetic fabric require special dyes and specific dyeing processes.

There are different methods of dyeing for fibers at particular stages. They include: stock dyeing (in the fiber stage), top dyeing (in the combed wool silver stage), yarn dyeing (fiber that has been spun into yarn), and piece dyeing (after the yarn has been constructed into fabric).

Stock-dyed fiber does not spin as readily as undyed fiber because it loses some of its flexibility during the dyeing process. For this type of dyeing a lubricant must be added in the final rinsing to overcome this spinning difficulty. The fiber dyed in this process is in a loose condition before being spun, and it is placed in large vats wehere the dye liquor is circulated through the fibers at high temperature.

Top dyeing is where the wool has been combed to take out the short fibers and is then wound on perforated spools where the dye liquor is circulated through. This process is used widely because of the even dyeing that can be achieved.

Yarn dyeing is where the yarn is dyed on a spool or is immersed in a dye bath. Piece dyeing is when the fabric is dyed after it has been woven into cloth and is dyed in large baths.

There are three major types of machinery used in the dyeing process. They are 1) padding dyers, 2) continuous dyeing machines, and 3) vat dyers. Padding is used to obtain an even distribution of the dye liquor throughout the cloth by first saturating it and then squeezing out the excess by passing the saturated goods between squeeze rolls arranged so as to apply even pressure across the piece. Continuous dyeing involves the motion of both the cloth and the dye liquor along a steam channel or spraying process.

This process is mostly used in the dyeing of large and continuous lengths of fiber. The vat dyeing process involves the use of different rotating devices which are submerged in large vats or vessels where the dye is then pumped in to completely immerse the fabric.

Production of the major groups of dyes is included in the following table:

Types of Dyes	Million of Pounds (1971)
Vat	51.6
Direct	31.4
Acid	24.1
Disperse	31.1
Basic	15.5

Dyes can be classified according to their usage. The major ones include:

1) Acid Dyes - used mostly on wool and silk, but also on dyeing acetate, nylon, acrylics, modacrylics, and spandex. Acid dyes are inexpensive and fairly fast to light.

a) simple acid dyes - nitro, nitroso, monoazo, diazo

b) mordant acid dyes - anthraquinone, monoazo

c) premetalized acid dyes - chromium, cobalt, iron (metals used to make the dyes)

2) Basic dyes - gives bright shades to silk and wool. Basic dyes are used with a mordant for cotten, linen, acetate, nylon, polyesters, acrylics, and modacrylics.

-diarylketonimine

-triarylmeltrane

-szine

-azo

-analine

3) Direct Dyes - dye cellulose fibers in bright, full, shades. Direct dyes are used on wool, silk, and nylon.

-Benzidine

-Tolidine

-Aniline

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4) Disperse Dyes - used in dyeing nylon, polyester, acrylic, modacrylic. These dyes are susceptable to nitric acid in the atmosphere and will gradually fade.

-aminoanthraquinones

-aminomonoazo derivatives

5) Vat dyes - these dyes are used mainly for cotton, linen, rayon.

-anthraquinones

-andigoid

The dyeing and refinishing industry involves a sophisticated knowledge of the types of fibers being used and the particular dyes that are compatible with these fabrics. The stage of the fabric, the dyes used to adhere to that fabric and the type of fabric are all critical factors in the dyeing and refinishing process.

B. Hazards

The general physical hazards associated with the dye industry include:

1) splashes of chemicals on extremities

2) fire and explosion hazards

3) hand and arm injury involving moving machinery

4) burns from contact with equipment

5) falls

6) excessive noise

The health hazards in the dyeing industry arise not only from exposure to specific dyes, but also from contact with reagents and solvents used in the processes. Therefore, the toxicity of individual dyes as well as their toxicity when in combination with other materials must be considered. The basic dyes are considered to be the most irritant of the dye groups.

Occupational dermatitis is one of the principle hazards to workers in the dyeing industry. Dyes as well as many other chemicals used in the industry are skin sensitizers. Some major areas of concern identified as causing dermititis are: acids, alkalis, mercurial salts, zinc chloride, moisture, bleaches, solvents, detergents, and the specific dyes. Chemical burns are also a problem in the dye industry. Corrosive alkalis and acids and boiling liquors used in the treatment of cloth all have the potential for causing chemical burns. Scalding accidents have occurred from exposure to the hot liquor solutions. A potential health hazard in the dye industry is exposure to chlorine, which is often used as a bleaching agent as

hypochlorite or gaseous chlorine. Chlorine is an irritant to the skin, eyes, and lungs, and should be strictly controlled. NIOSH published a criteria document on chlorine in 1976.

Inhalation of dust is a potential hazard to dyers. Generally, the basic dyes are the most irritant of the dye classes. In this class, the salts of the aromatic amines can produce respiratory sensitization and asthma. A group of azoic dyestuffs, known as "fast salts," also present an inhalation hazard. These compounds are diazonium salts of aromatic amines. T hey are not actually dyes, but are reacted with other chemicals such as naphthols to form a dye on the fabric. They also can produce respiratory sensitization and asthma. The other classes of dyes in general are considered to have little irritant effect following inhalation.

Certain dyes and dye intermediates have been identified as being carcinogenic. These include rhodamine B, magenta, naphthylamine, dianisidine, and benzidine. However, epidemiologic evidence has not made it clear if it is the intermediates or the dyes themselves that cause cancer. Benzidine and alpha- and beta-napthylamine, used in the production of azo dyes were included in a list of 14 carcinogens, published by OSHA in 1974. Case et. al. reported in 1954 that workers engaged in both the manufacture and use of benzidine are at an increased risk of developing bladder cancer. In the case of the dyes magenta and auramine there is no evidence of workers who use these compounds developing cancer. However, workers involved in the manufacture of these two dyes have veen shown to have an increased risk of developing cancer.

ACGIH (TLV) (1976) for aniline (skin): 5 ppm (19 mg/cu m)

C. Extent of Exposure

1) Current

Number of establishments, excluding wool:	655
Number of employees (wool finishing):	30,000
Number of employees (all other textiles):	80,000

2) Future

Since 1950 the dye and finishing industry has been increasing gradually overall. Sudden drops are noticeable in years where market conditions dictated less dyes, however the general trend has been increasing. Although no predictions for the future market have been made, it is reasonable to assume that the general increase will continue and production of dyes will increase. However, there will probably continue to be a shift from the natural wools and cottons to the fabrics that include synthetic rubbers and plastics.

D. Environmental and Epidemiological Data

Presently a study is now being conducted to examine the medical records and death certificates of 2,000 members of the American Textile Workers Union to identify the incidence of bladder cancer.

This study follows up a study conducted in 1934 by Heuper where he investigated the history, significance, and epidemiologic evidence of "aniline cancer" in the dye industry. Heuper stated that aniline, benzidine, and naphthylamine were causes of bladder cancer. He discribed the pitfalls of this study as:

1) workers were exposed to more than one chemical

2) differing degrees of exposure hazards

3) unsuspected impurities in trace amounts

4) different composition of dyes.

E. Illness and Injury Statistics

	Total Cases of Injury and Illness/100	Lost Workdays/ 100 Cases
wool textiles	13	91
non-wool textiles	13	94
mining	10.2	94.7
contract construction	18.3	99.8
national average	10.4	54.6

F. Summary

Dyeing and Refinishing Textiles

SIC No. 2231

Extent of Exposure

number of employees - 110,000

Economic Trend - a gradual, consistent increase in the production of dyes.

Environmental Data

Studies have shown there is a possibility of bladder cancer in the dye industry.

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WOOD PRESERVING

SIC No. 2491 Wood Preserving

This industry includes the cutting, treating, and selling of poles, posts, and piling, but establishments primarily engaged in manufacturing other wood products, which they may also treat with preservatives, are not included.

- Bridges and trestles, wood
- Crossties
- Flooring, wood block
- Millwork
- Mine props
- Piles, foundation and marine construction
- Piling, wood
- Poles and pole crossarms
- Poles, cutting and preserving
- Posts, wood
- Railroad cross bridge and switch ties
- Structural lumber and timber
- Vehicle lumber

A. Description of Process

Chemical treatment of wood to impart fire, mold, or pest resistance entails immersion of the wood in or injecting it with oils, metal salts, or organic compounds. Wood products intended for outdoor use, such as crossties, fence posts, utility poles, and marine pilings, comprise the greatest volume of wood preserved. Wood preservation processes can be classified as "pressure," whereby the wood is conditioned with heat and steam or vacuum treatment, then impregnated under heat and pressure with preservative, or "non-pressure," whereby the wood is simply immersed in a hot or cold preservative solution in an open tank. The pressure process is used by more than 80% of wood treatment plants. For both processes, the wood is loaded into large tanks, and the preservative solution is piped in. After the appropriate treatment and time interval, the preservative is drained and processed for re-use, and the wood is unloaded.

Preservatives in use include creosote, tar, lignite oil, mineral oil, organometallic compounds, metal salts, tetra-and penta-chlorophenol and their metal salts, chlorinated naphthalenes, chlorinated methane and ethane derivatives, nitro compounds, and naphthenates. Creosote and pentachlorophenol (PCP) formulations are by far the most widely used wood preservatives in the US, and together accounted for about 86% of the total amount of wood preserved over the past five years.

B. Hazards

The potential for health or safety hazards varies greatly, depending on the size of the operation, the product being processed, and the degree of automation. Hazards which may be encountered include contact with preservative from splashes, spills, or leaks. Preservative operations are usually outdoors and fairly large scale, where wood is transported to the treatment site on rail cars and loaded directly into large cylindrical pressure tanks. Following pressure-preservative treatment, after the solution has been drained, the end hatch is opened for removal of the wood. This may be automated, or may be done manually, which can result in liquid and vapor exposure. There are

often puddles of preservative on the ground around the tanks, which can be a skin contact problem. In addition, the tanks must be periodically cleaned, a process which may be semi-automated or manual.

Toxicities of Specific Preservatives (human)

Pentachlorophenol (C_6Cl_5OH) and sodium pentachlorophenol (C_6Cl_5ONa) (Santophen 20, Penta, Dowicide 7, Penchlorol, PCP, Cuprinol, Evrisan; Santobrite): may be absorbed through the skin; PCP dusts or solutions can cause dermatitis and systemic intoxication following prolonged or repeated skin contact; can cause lung, liver, and kidney damage; can cause irritation of mucous membranes of nose, throat, and eyes; more toxic in organic solvents.

TLV (ACGIH): 0.5 mg/cu m

Creosote (cresotum, creosote oil, brick oil): Vapors cause eye and nose irritation, liquid creosote is a primary skin irritant, but not an eye irritant (EPA report); irritation thresholds for eyes, nose and throat have not been determined; photosensitization has been reported; fair skinned people are reportedly sensitive to creosote (vapor or liquid exposure not specified); cutaneous carcinomas are reported to involve hands, forearms, scrotum, penis, neck, and face; available information regarding these cases indicates gross contact of skin and clothing, minimal protective measures and minimal personal hygiene.

Maximum allowable concentrations have not been established.

C. Extent of Exposure

Average number of employees, total: 12,000

D. Injury and Illness Statistics

	Total Cases of Injury and Illness/100	Lost Workdays/ 100 Cases
Wood Preserving	22	117
Mining	10.2	94.7
Contract construction	18.3	99.8
National Average, All Occupations	10.4	54.6

F. Current and Future Trends

Use of PCP as a wood preservative has followed an increasing trend, and for some applications is slowly replacing creosote. In 1973, 38.8 million pounds active ingredient of PCP and its sodium salt were used, accounting for 32% (80,648,000 cubic feet) of all wood preserved. Creosote formulations accounted for 51% (129,965,000 cubic feet) of all wood preserved. PCP is preferred for use on utility poles, fence posts, window frames, and doors. Creosote is preferred for railroad ties and marine and foundation pilings.

Preserved wood products face continuing competition from nonwood products. Prices of wood are strongly influenced by prices of the substitute products, and tend to be set below the substitute if there is strong competition.

PCP and creosote, along with water-borne arsenic salts, occupy unique seqments of the wood preservative market. Future use of these products depends on their future availability pending current Environmental Protection Agency decisions concerning registration of all three products.

G. Other

A recent NIOSH criteria document was published on organotin compounds, wood preservatives of minor but increasing importance in this country. In addition, a criteria document on coal tar pitch of which cresote is a component, is now in preparation.

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8. All injury and illness and lost workday statistics are from data supplied by NIOSH.

PULP AND PAPER MILLS

SIC No. 2611 Pulp Mills

A. Description of Process

Pulp used for paper products manufacture may be derived from rags, straw and grass, waste papers, and cotton linters, but wood is by far the most common source.

The two major pulping processes in use in this country are the sulfate (kraft) process, accounting for about 61 percent of production, and the sulfite process, accounting for 12 percent. The remainder is produced by mechanical processes, by combination (semi-chemical) processes, and by miscellaneous processes, some of which are experimental or pilot operations. Because of the small amount produced or because of the relatively innocuous chemicals used, the potential hazards of these latter methods are of less importance than those of the sulfite and sulfate processes.

For both processes, bark is removed from logs either by tumbling or rotating, or with high-pressure jets of water. The logs are converted to small chips, which are transferred, usually as a slurry, to digesters, and cooked at 150 C and high pressure in chemical liquor, the composition of which depends on the process. From a "continuous" digester, pulp emerges continuously, and is washed and screened repeatedly to remove the cooking liquor. From a batch digester, the whole mixture is blown into a "blowpit" and is simultaneously washed with water. The clean pulp is bleached with chlorine dioxide, then neutralized and treated with calcium hypochlorite.

In the sulfite process, wood is digested under acidic conditions with solutions of magnesium bisulfite and sulfur dioxide in large towers. After the digesting process, the pulp is separated from the spent liquor, which is evaporated and separated into magnesium oxide and sulfur dioxide. The magnesium oxide is slaked to form magnesium hydroxide. Magnesium hydroxide and sulfur dioxide are combined with water to form magnesium bisulfite, which is reused as cooking liquor. Calcium, sodium or ammonia can be used in place of magnesium, but cannot be as efficiently recovered.

The sulfate (kraft) process is similar to the sulfite process, except that the pulp is cooked under alkali conditions using sodium hydroxide and sulfide and bisulfide ions. Spent liquor from the digesters contains both the chemicals (sodium sulfide combined with organic sulfur compounds and sodium carbonate, and small amounts of other substances) and about half the original content of wood. This mixture is evaporated, then sprayed into a smelting furnace where the woody residue burns away and the inorganic chemicals are melted.- Sodium sulfide and sodium carbonate are recovered, and go into a tank to which calcium hydroxide is added.

Sodium carbonate and calcium hydroxide combine to form sodium hydroxide and calcium carbonate. The sodium sulfide and sodium hydroxide go into a storage tank, for reuse as cooking liquor. The calcium carbonate is converted to calcium hydroxide in a causticizing tank.

B. Hazards—Pulp Mills

- Dust hazards. Wood dust is a potential fire and explosion hazard; bark dust can contain mold spores which can produce respiratory ailments. Lime dust may be a problem in loading areas.

- Hot, humid atmospheres, as may be encountered in drying rooms and in the boiling, washing, and chemical recovery areas. Respiratory ailments and rheumatism are somewhat more common in people working in such areas.

- Exposure to cooking liquors and by-products. Clinical reports and ad hoc surveys have reported respiratory irritation, bronchitis, and decreased lung capacity in pulp mill workers, usually attributed to chlorine, chlorine dioxide, hydrogen sulfide, and sulfur dioxide. Many reports indicate that these effects occurred when a TLV was exceeded frequently or over prolonged periods. Other exposures are in the form of particulate aerosols, vapors, and possibly liquids. Potentially hazardous substances which may be encountered in the sulfate (caustic) process include: sodium hydroxide,[1] -sulfide,[1] and -bisulfide, calcium hypochlorite, hydrogen sulfide,[1] calcium oxide, and mercaptans. In the sulfite (acid) process, these include: calcium bisulfite, sodium bisulfite, magnesium bisulfite, ammonia,[1] magnesium oxide, and sulfur dioxide.[1] Compounds common to both processes include chlorine,[1] chlorine dioxide, and mercury compounds.[1] The health consequences of long-term exposures to most of these substances have not been determined.

- A large scale survey of deaths of workers in wood-related operations showed an apparent excess of Hodgkin's disease; this study, however, did not differentiate among specific wood-related occupations.

PAPER MILLS

SIC No. 2621 Paper Mills, Except Building Paper Mills

Establishments primarily engaged in manufacturing paper (except building paper-Industry 2661) from wood pulp and other fibers, and which

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[1] A NIOSH criteria document has been or is being prepared on this compound.

may also manufacture converted paper products. Pulp mills combined with paper mills, and not separately reported, are also included in this industry.

SIC No. 2631 Paperboard Mills

Establishments primarily engaged in manufacturing paperboard, including paperboard coated on the paperboard machine, from wood pulp and other fibers; and which may also manufacture converted paperboard products. Pulp mills combined with paperboard mills, and not separately reported, are also included in this industry.

SIC No. 2661 Building Paper and Building Board Mills

Establishments primarily engaged in manufacturing building paper and building board from wood pulp and other fibrous materials. Pulp mills combined with building paper and building board mills, and not separately reported, are also included in this industry.

A. Description of Process

Up to 88 percent of all pulp is produced at combination pulp and paper mills. In these integrated operations, the pulp is usually delivered directly to the paper mill as a slurry. Purchased pulps are received as dry sheets, and must be slushed before use. All pulps must be subjected to mechanical action ("beating") before being formed into paper sheet, and the equipment used for this is varied.

Paper processing includes:

- Filling and loading: Fillers improve brightness, opacity, softness, smoothness, and ink receptivity. Those in use include kaolin or China clay, titanium dioxide, calcium carbonate, zinc sulfide, and lithopone.

- Sizing: This is the addition of materials to the paper so that the sheet is more resistant to penetration by liquids. Sizing agents include rosin, various hydrocarbons and natural waxes, starches, glues, casein, asphalt emulsions, synthetic resins, and cellulose derivatives.

- Coloring: Most dyes are added to the stock in the beater; some dry paper is colored by dipping or by applying a dye solution at the calenders. Water-soluble synthetic organic dyestuffs are the most widely used. Some water insoluble but dispersible pigments, such as carbon black, vat colors, and sulfur colors, are also used.

- Other additives: Starches, natural gums, modified celluloses, such as carboxymethyl and hydroxyethyl derivatives, and polymers of the urea-formaldehyde and melamine-formaldehyde types are used for providing wet strength to the finished sheet.

- Sheet forming and drying: Several forming devices are in commercial operation, but as these are usually enclosed and fully mechanized, hazards are minimal.

- Pigment coatings: These consist of compositions of pigments, adhesives, and additives, which are used to mask the appearance of base stock, improve opacity and writing surface, etc. Various types of machinery may be involved in this process, but basically, an excess of coating is applied and smoothed; drying methods include air or convection drying, contact, or radiant energy (IR) drying.

  - Pigments used include clays, muscovite mica, attapulgite, talc (which is usually used with a wetting agent, such as polyoxyethylene or polyoxypropylene), titanium dioxide, calcium, carbonate, aluminum oxide hydrate, barium sulfate, silica, calcium sulfate, and zinc oxide.

  - Adhesives used include casein (often in combination with borax or ammonia), soy protein. starch (may be used in combination with urea- and melamine-formaldehyde or glyoxal), polyvinyl alcohol, rubber latexes, acrylic emulsions, and polyvinyl acetate.

  - Additives include dispersing agents (usually a polyphosphate), stabilizers, foam control agents (pine oil, capryl and tridecyl alcohol, fuel oil, tributyl citrate and phosphate, and silicones), lubricants, plasticizers, and flow modifiers (soluble and insoluble soaps, sulfated oils, wax emulsions, amine products, and esters).

  - Miscellaneous other additives include urea and dicyandiamide, used to reduce viscosity, humectants (e.g., glycerol derivatives), urea or melamine-formaldehyde resins, or zinc, aluminum or other metal salt solutions for water resistance.

- Barrier coatings: Paraffin wax may be used in combination with polyethylene or ethylene-vinyl acetate copolymer. Solvent systems include organosols and plastisols, cellulose and rubber derivatives, polyamides, polyesters, and alkyds.

B. Hazards--Paper Mills

- Dermal and inhalation exposure to the many various compounds mentioned in the process section. Of particular concern are pigment and coating dusts, which may be encountered in loading operations, inhalation or skin absorption of toxic solvents which are present in the various glues, adhesives, and coatings, and dermatitis, both irritant and sensitizing.

- Respiratory symptoms have been associated with teflon fumes emitted by heaters.

- A large-scale survey of deaths of workers in wood-related operations showed an apparent excess of Hodgkin's disease; however, this study did not differentiate among specific wood-related occupations.

In 1974, about 2,210,000 short tons of sulfite pulp and 33,000,000 short tons of sulfate pulp were produced in the U.S., accounting for about 73 percent of total wood pulp production. Total paper and paperboard production for 1975 was estimated to be about 52,200,000 short tons. In the past several years, these levels have remained fairly constant. Recent developments in paper and pulp technology, including computer control, closed loop systems, continuous digesters, improved chemical pulping and chemicals recovery processes, oxygen bleaching, and improved pulp handling and drying, have led to increased production efficiency and undoubtedly, some change in risk of hazardous occupational exposures and personnel requirements. Some factors which could seriously affect the industry include increased competition from plastic substitutes (however, escalating crude oil processes could reduce cost-competitiveness of petroleum-based plastics versus pulp-based products) and increased costs of natural gas. The volume of output is expected to increase slowly in the next decade, with most of the rise in value of shipments resulting from higher prices.

C. Extent of Exposure and D. Illness and Injury Statistics

	No. of Establish-ments	Avg. No. Employees	Avg. No. of Production Workers	Total Cases Of Injury and Illness/100	Lost Workdays/ 100 Cases
Pulpmills	60	10,600	8,400	18.7	72
Papermills (SIC #2621)	349	129,900	103,300	11.8	79
Paperboard Mills (SIC #2631)	273	68,500	54,500	14.7	93
Building Paper & Board Mills	92	11,600	9,900	18.0	128
Mining	-	-	-	10.2	94.7
Contract Construction	-	-	-	18.3	99.8
Nat'l.Avg. All Occupations	-	-	-	10.4	54.6

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SECONDARY SMELTING AND REFINING OF NONFERROUS METALS

SIC NO. 3341

These establishments are primarily engaged in recovering nonferrous metals and alloys from new and used scrap and dross. This industry includes establishments engaged in both the recovery and alloying of precious metals. Plants engaged in the recovery of tin through secondary smelting and refining, as well as by chemical processes, are included in this industry.

A. Description of Process

Processes vary depending on type of material being recovered, associated manufacturing or recovery operations, size of business, etc., but in general, secondary smelting and refining involves the melting of scrap material in large furnaces so that the metal is pooled and the non-metallic scrap volatilized. The molten metal may be purified by leaching with a strong acid or alkali, and possibly treated by electrolysis.

Secondary reclamation smelters range in size from very small to fairly large operations, with industrial hygiene controls varying from none to adequate. They may exist as adjunct operations to specific manufacturing processes. Examples are the recovery of precious metals in plume dust of photographic chemicals plants, the resmelting of copper wire scrap in the production of cable, and the reprocessing of new articles rejected for sale because of defects. They may be independent reclamation businesses specializing in particular used-scrap products, such as lead batteries.

B. Hazards

Potential hazards include heat stress, molten metal splashes, gases, dusts, fumes, and noise. In addition to the hazards associated with the primary metal being refined, materials that are a part of the scrap, such as caulking, casings, wire and cable insulation, and protective coatings and paints are potentially hazardous contaminants. The fumes of a variety of these substances may be encountered simultaneously during initial stages of smelting when these materials volatilize.

As practically no data regarding hazards or epidemiology specific to secondary smelting and refining were found, representative potentially harmful exposures have been identified and are treated individually below.

Some general hazards include:

- Metal fume fever: This is an acute, influenza-like syndrome induced by inhalation of finely divided particles of metals. It is most often associated with exposure to zinc oxide fumes, but is also known to occur

following exposure to Sb, As, Be, Cd, Co, Cu, Pb, Fe, Mg, Mn, Hg, Ni, and Sn. Onset of illness occurs several hours after exposure, and symptoms include malaise, chills, fever, nausea, and vomiting. The condition usually lasts less than a day, and is never fatal. Immunity develops upon repeated exposure, but is lost if exposure ceases for even a few days. According to the ILO Encyclopaedia of Occupational Health and Safety, metal fume fever is very common, and tends to be accepted as an associated hazard of the job.

- Polymer fume fever: This is an influenza-like syndrome similar to metal fume fever. It generally lasts less than two days, and requires only symptomatic treatment. It occurs when workers are exposed to decomposition products of tetrafluoroethylene resins heated to 315-375 C, and is thought to be due to particulates, rather than to any specific chemical effect.

- Inhalation of toxic gases: Toxic gases can be generated by pyrolysis or combustion of polymer products, such as plastics and rubbers. Examples include hydrogen fluoride and octafluoroisobutylene from polyfluorines, and hydrochloric acid, vinyl chloride, and possibly phosgene from polyvinyl chloride

1. Lead Scrap Recovery

Electric storage batteries provide the major single source of raw material in the secondary smelting and refining industry. Batteries account for nearly 50 percent of the total U.S. consumption of lead as lead oxide and antimonial lead. Of this, about 80 percent is resmelted as scrap.

Secondary lead smelting is considered to be a high risk operation, which is often performed under primitive conditions. Hazards include:

- exposure to high concentrations of lead fumes, as are generated at the elevated temperatures required for smelting; emptying of the smelting furnace is a particularly hazardous procedure in this regard.

- lead oxide dust, as arises from lead battery plates, which tend to deteriorate and crumble readily when dry.

- sulfuric acid, which is a component of batteries, and which may or may not be removed prior to smelting

- fumes of complex polymeric substances, as may be generated by burning battery casings; battery casings can be constructed of hard rubber, composition (coal tar pitch, asbestos, slate dust, lime), or plastics (polystyrene, acrylonitrile, acrylonitrile-butadiene-styrene).

Additional sources of exposure to lead in secondary smelting and refining include:

- as incidental solder, caulking, or covering
- as a component of metal alloys in a variety of scrap materials
- as a pigment in metal coatings. Though its use is declining, red lead (Pb_3O_4) is still the most important lead pigment for metal coating. Other metal coatings contain varying amounts and compounds of lead.

A recent report by a group in Finland showed lead scrap smelter workers to have the highest blood lead levels (79 ug/100 ml) of 30 different lead-working occupations surveyed. No published reports of similar studies conducted in the U.S., nor of systematic measurements of lead in the air of lead-using industries have been found.

A NIOSH criteria document has been prepared on inorganic lead.

Production figures for lead derived from secondary sources have followed a generally increasing pattern over the years for which figures are available. In 1974, production totalled about 632,000 short tons, accounting for about 48 percent of total U.S. lead production.

2. Selenium

Selenium is used in alloys, pigments, and as a fireproofing component of electrical cable. Exposure may be to fumes and dusts of elemental selenium, its oxides, hydrates and organic compounds.

Effects of chronic intoxication include mucuous membrane irritation, abdominal pain, nausea, vomiting and lumbar pain. Delayed pulmonary edema in copper refinery workers has been reported.

According to a review of a paper by the ACGIH Documentation of TLV's, 35 of 62 workers employed in a selenium rectifier plant, where concentrations of "selenium" (identity of compound unclear) ranged from 0.007 to 0.05 mg/cu m, complained of symptoms including headache, conjunctivitis, and slight tracheobronchitis.

Two to three hundred workers in a similar plant, where selenium concentrations ranged from 0.2 to 3.6 mg/cu m, showed skin rashes, indigestion, metallic taste, garlic-smelling breath, and various socio-psychological effects.

ACGIH (1976) TLV, selenium compounds, 0.2 mg/cu m

ACGIH (1976) TLV, selenium hexafluoride, 0.4 mg/cu m

Production figures for selenium were not found.

3. Antimony

Antimony is used in lead, tin, and copper alloys, and as a component of ceramics, glass, plastics, enamels, and paints. Occupationally-related inorganic antimony poisoning is uncommon. Stilbine (SbH_3), a gas that occurs as a result of acids reacting with certain antimony compounds or by the action of nascent hydrogen on antimony, may present an inhalation hazard. Acute exposure can cause symptoms similar to those caused by arsine, which include chills, headache, nausea, abdominal cramping, jaundice, and oliguria or anuria. Chronic poisoning in man has not been reported.

ACGIH TLV, notice of intended changes for 1976:

antimony trioxide, handling and use, 0.5 mg/cu m

antimony trioxide production, 0.05 mg/cu m

Secondary production of antimony in the U.S. has maintained a fairly constant level over the past 30 years. In 1974, 21,100 short tons of antimony and antimonial lead (separate figures are not available) were produced, accounting for 58% of total antimony production.

4. Zinc

Zinc is a component of brass and is also alloyed with nickel, aluminum and magnesium. Zinc oxide and the salts of zinc ($ZnCl_2$,$ZnSO_4$) are used in pigments.

Metal fume fever is caused by many metal oxides (Sb, As, Be, Cd, o, Cu, Pb, Fe, Mg, Mn, Ni, Sc), but is most often reported in association with exposure to zinc oxide fumes. As zinc oxide is the subject of a NIOSH criteria document, its effects will not be discussed here.

According to reviews by the ACGIH Documentation of TLVs, exposure to zinc chloride fume can cause: damage to mucous membranes of the nasopharynx and respiratory tract, ulceration of exposed skin surfaces, and pale gray cyanosis.

ACGIH TLV, zinc oxide fume, 5 mg/cu m

ACGIH TLV, zinc chloride fume, 1 mg/cu m

5. Copper

Non-ferrous copper alloys include brass (copper and zinc), and bronze (copper and tin). Copper is also alloyed with nickel, aluminum, gold, lead, cadmium, chromium, beryllium, silicon, and phosphorus.

Inhalation of copper salt dusts, fumes, and mists can cause congestion of the nasal mucous membranes and ulceration with perforation of the nasal septum. Copper metal fumes can cause nausea, gastric pain, and diarrhea. According to the ACGIH Documentation of TLV's, chronic exposures may result in anemia. Dermal exposure to copper salts can cause itching eczema. Eye exposure can result in conjunctivitis or ulceration and turbidity of the cornea.

ACGIH (1976) TLV, copper fume, 0.2 mg/cu m

ACGIH (1976) TLV, copper dusts and mists, 1 mg/cu m

Secondary production of copper has been increasing, due partly to the recent dramatic increase in the price of copper. The estimated U.S. production for 1974 is 1,313,000 short tons, accounting for about 43% of total copper production for that year.

6. Other toxic metals which may be the primary metal being recovered or may be present as alloy components or contaminants, include: arsenic, barium (present in alloys with Ni, Ti, Pb, Mg), beryllium (alloyed with Cu, Ni, Al), cadmium (alloyed with Cu; also used for electroplating and as a paint pigment), chromium (used as an alloy component and for metal plating), cobalt (used in alloys, enamels, pigments, glazes, and metal plating), gold, mercury (present in amalgams with Cu, Sn, Ag, Au; also used in the manufacture of Al, platinum, silver), and tellurium (used in dyes and pigments and as an additive to nonferrous metals).

C. Extent of Exposure

Establishments, total	381
Average number of employees, total	17,800
Average number of production workers	13,100

D. Illness and Injury Statistics

	Total cases of injury and illness/100	Lost workdays/100 Cases
secondary smelting and refining of non-ferrous metals	31	202
mining	10.2	94.7
contract construction	18.3	99.8
national average, all occupations	10.4	54.6

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MANUFACTURING OF NON-METALLIC PIGMENTS AND DYES

SIC No. 2865

The non-metallic pigments and dyes discussed here are all synthetic organic compounds. These pigments and dyes are distinguished by method of application or by degree of solubility rather than by chemical composition and manufacture. Pigmentation is accomplished by dispersion, a finely divided insoluble solid that is placed directly into the vehicle without prior solubilization. Coloration by dyes are effected with its application to a fabric in a soluble form and then fixed by being rendered insoluble. Dyes actually are chemically bound and thus become part of the material to which they are applied. Since there are great similarities in the chemistry and production of non-metallic pigments and dyes, the following discussion will be limited to dyes, but will largely apply to pigments as well.

Inorganic pigments and dyes are excluded from this discussion because they contain metals. Carbon Black and Silicon Dioxide are also excluded as they are included in NIOSH's Criteria Document program.

A. Description of Process

MANUFACTURE OF DYE INTERMEDIATES AND DYES

Raw Materials

Products recovered from fractional distillation of coal tar have been the traditional primary source of organic raw materials for the production of dyes. "Synthetic dyes" are often referred to as "coal tar dyes." The most important of the coal tar products for the dye industry are benzene, toluene, xylene, naphthalene, anthracene, acenaphthene, pyrene, pyridine, carbozole, phenol, and cresols. The petroleum industry is now supplying an increasing proportion of these primary raw materials, particularly benzene, toluene, xylene, and naphthalene.

A great variety of inorganic chemicals are also used in dye manufacture as reagents and solvents, including sulfuric acid, oleum, nitric acid, chlorine, promine, caustic soda, caustic potash, sodium nitrate, hydrochloric acid, sodium carbonate, sodium sulfate, sodium hydrosulfite, sodium sulfide, aluminum chloride, sodium dichromate, manganeze dioxide, and iron powder.

The Manufacturing Equipment and Processes

A great number of intermediates are used to manufacture dyes, and where their use is confined to the manufacture of dyes, comparatively small tonnages are involved. Therefore, manufacture of many of these chemicals by a continuous process would be uneconomical. Anthraquinone is one of the few intermediates used solely by the dye industry that is made by a continuous process. Phthalic anhydride, aniline, and phenol are also intermediates used by the dye industry in large volumes and are manufactured by continuous processes, but the bulk of consumption of these materials is by other industries. Most of the intermediates used by dye manufacturers are made using batch processes.

The batch processes are carried out in reaction kettles made from cast iron; stainless steel; or steel lined with rubber, glass (enamel), brick, carbon blacks or stainless steel. These kettles generally have capacities of 500-10,000 gallons, and are equipped with mechanical agitators, thermometers, and condensers, depending on the nature of the operation. Products are transferred from one piece of equipment to another by gravity flow, by pumping, or by blowing with air or inert gas.

Separation of solid products from liquids is performed using plate and frame filter presses, filter boxes, and centrifuges. When possible, intermediates are used for subsequent manufacture of other intermediates or dyes without drying. When drying of intermediates is required, air or vacuum ovens (product spread on trays) and rotary ovens are used. Drum dryers (flakers) and spray dryers are less frequently used.

The major process steps occuring from the addition of raw materials to the reaction kettles to the separation of the solid dye material may take place in an open or closed system. The transfer of solid materials to drying ovens or areas is a manual process, as is the handling of the material after drying. Monitoring of the reactions is usually manual, although automatic process control based on feedback from temperature, redox potential, and pH measurement is finding increasing use in the dye industry.

Outlined below are the major chemical steps in the manufacture of dyes and the most common reactions which take place in these steps.

Step 1 involves attack on the aromatic hydrocarbon raw material, introducing one or more groups. Common reactions which occur during this step are sulfonation, nitration, halogenation, Freidel-Crafts reaction, and oxidation.

Step 2 usually involves replacement or conversion of substituents introduced by Step 1 reactions, by groups of higher reactivity which cannot be introduced directly; Step 2 reactions serve to furnish the groups OH, NH_2, CN, OR, SR, and NRR', where R and R' are hydrogen, alkyl, or aryl.

Step 3 involves further modification or development of functional groups already introduced into the aromatic nucleus. Almost all of the reactions and techniques of the organic chemist are used in this step. The reactions may include those mentioned in Steps 1 and 2, with the conditions suitably modified for the changed electronic state of the molecule. There are, however, many reactions which may only be applied to groups introduced by Step 2 reactions. These include the Sandmeyer reaction, alkylation, acylation, Kolbe-Schmitt reaction, nitrosation, and benzidine rearrangement.

Step 4 reactions include diazotization and coupling, condensation, and dimerization. These reactions are those which essentially combine two intermediates to form a product having a skeletal if not complete dye structure. Many of these products may also be intermediates in synthesis of dyes of greater complexity.

Production of Dyes

Listed below are the major classes of dyes and their production figures. The total production of synthetic dyes in 1974 was 275 million pounds. Production trends show an increasing manufacture of dyes.

Azo dyes are produced by the coupling of a diazolized aromatic amine to a phenol, amine, pyrazolone, or other coupling component. In 1972, 92.0 million pounds of azo dyes were produced. Production of these dyes is increasing. Listed below are the 1971 figures for production of dyes within this class:

Monoazo	33.4 million pounds
Disazo	26.0 million pounds
Triazo	9.4 million pounds
Polyazo	2.4 million pounds
Other	10.8 million pounds

Anthraquinone dyes are condensed polycyclic quinonoid dyes. The U.S. production is primarily through anthraquinone intermediates based on benzene and phthalic anhydride. In 1972, 46.6 million pounds were produced. Production has shown a slight decline since 1968, in which 55.1 million pounds were produced.

Stilkene dyes. In 1972, 30.9 million pounds of stilkene dyes were produced. The production of stilkene dyes has shown a slight decline since 1969.

Sulfur dyes are applied in a reduced state from solutions containing sodium sulfide, hydrosulfide, or polysulfide which are subsequently oxidized on the fiber. They are mainly used in dyeing cellulosics (cotton and viscose rayon) and leather. Production was 18.5 million pounds in 1969.

Azoic dyes are insoluble dyes formed in situ by the reaction of a "coupling component" (naphthol) with a diazotized aromatic amine, and are used mainly on cellulosic fibers (cotton), but also on nylon and fur. In 1972, 10.3 million pounds were produced and production is increasing. The production breakdown for the azoic dyes and components in 1971 was:

Azoic compositions	3.5 million pounds
Azoic diazo components, base (fast color base)	1.4 million pounds
Azoic diazo components, salts (fast color salts)	3.2 million pounds
Azoic coupling components (naphthol AS derivatives)	2.3 million pounds

Triarylmethane dyes. In 1972, 8.9 million pounds were produced.

Indigoid and thioindigoid dyes are produced from aniline intermediates which can be either synthesized from coal tar or derived from natural indigo. In 1970, 7.5 million pounds were produced.

Other. In 1972, 74.6 million pounds of other dyes, including acridine, amino-ketone, azine, indophenol, keton amine, nitroso, oxidation bases, and thiazine dyes were produced.

Production of Colored Synthetic Organic Pigments

Production (1974)	thousands of short tons (net weight)
Azo	19.632
Non-azo	12.228
-Basic	1.86
-Condensation Acid	2.829
-Phthalocyanine	7.334
Other	3.039
Total	34.899

Individual Pigment Colors Produced in the Largest Quantities

	thousands of short tons (net weight)
Benzidine Yellow	7.0 - 1974
Phthalocyanine Blue	5.6 - 1974
Lithol Red	3.9 - 1974
Alkalai Blue	2.2 - 1972
Phthalocyanine Green	1.8 - 1974
Permanent Red 2B	1.3 - 1974
Red Lake C	1.8 - 1974

The production value of synthetic organic pigments has grown at an average annual rate of 6.8% compared with a rate of growth of 4.6% for dyes during the years 1950-1974. Organic pigments have experienced a higher rate of growth partly because they are adaptable to many uses: plastics, printing inks, rubber, paints, and resin materials. Pigments are also replacing some of the more expensive dyes in the textile industry. Dyes are mainly used in the textile, leather, and paper fields.

B. Hazards

The hazards of dye manufacture arise largely from the toxicity of the primary and intermediate compounds, and from the reagents (such as acids and alkalies, and irritant and asphyxiant gases) and solvents used in the synthesis. Dermal and/or respiratory exposure to the raw materials, reagents, and solvents may occur during the manual addition of these substances to the reaction kettles. Manual monitoring of dye reactions may result in dermal exposure to the dye-intermediates. Inhalation of dust containing dyes or dye intermediates, or both, is likely to occur during the handling of these materials after drying.

The possible synergistic effects of the major raw materials, reagents, and solvents, as well as their individual toxicities, should be considered in evaluating dye-worker hazards, since there is exposure to many compounds during the manufacturing process.

Several dye-intermediates have been identified by OSHA as carcinogenic. These are benzidine, 3,3' dichlorobenzidine, 4-dimethylaminoazobenzine, alpha-naphthylamine (1-NA), and beta-naphthylamine (2-Na). Another dye intermediate, 4-nitrobiphenyl (4-NBP), has been identified as a carcinogen, however production of this compound was discontinued in the 1950's.

In general, the dyes are considered to be generally non-toxic, or of a low order of toxicity. It must be emphasized, however, that some dyes may contain significant amounts of the carcinogenic intermediates. Skin problems can come about through the use of strong cleansers to remove dye stains from the hands. A sodium hypochlorite solution is used for this purpose; hypochlorite is itself a powerful irritant. With the exception of the class of basic dyes, the dyes have little irritant effect.

C. Epidemiology

In 1934, Hueper reported the history, significance, and epidemiologic evidence of "aniline cancer" in the dye industry. The term "aniline cancer" was used to denote cancer of the urinary bladders in workers employed in the "aniline" dye industry. Hueper identified aniline, benzidine, and naphthylamine as the principal etiologic candidates, but emphasized some major difficulties in the study:

1. Workers were exposed to more than one suspect compound and this was further complicated by workers shifting between departments.

2. The degree of exposure hazard was not the same in all of the processes studied.

3. The presence of unsuspected impurities in trace amounts.

4. The composition and method of production of the dyes was not the same in all of the factories.

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CAISSONS AND COMPRESSED AIR TUNNEL WORK

The following Standard Industrial Classifications may include caisson and compressed air tunnel work: 1311 (Crude Petroleum and Natural Gas), 1382 (Oil and Gas Field Exploration Services), 1389 (Oil and Gas Field Services not Elsewhere Classified), 1622 (Bridge, Tunnel, and Elevated Highway Construction), 1623 (Water, Sewer, Pipe Line, Communication and Power Line Construction) and 1629 (Heavy Construction, not Elsewhere Classified).

A. Description

Caissons are structures used in underwater construction. Essentially they are inverted hollow boxes, made and maintained water-tight by means of compressed air. Two central shafts extend from the working chamber to the surface: one for removing silt, and the other for the entry and exit of workers. A decompression chamber is usually on the top of the caisson, where the crew decompresses at the end of each workshift.

Compressed air tunneling is used in operations where the presence of water is an obstacle, as in tunneling through porous sand or mud, or tunneling under bodies of water. An airtight bulkhead must be erected across the tunnel so that pressure may be applied to the working face. A decompression lock for the workers is provided in the space created by the construction of a second bulkhead.

Due to practical structural considerations, the maximal pressure in tunnels and caissons is usually limited to 50 psig. Compressed air is at this time the only gas used for compression of these structures.

B. Hazards

The principle health hazards encountered in both tunneling and caisson work are those associated with compression and decompression, so the parts of this section on those problems cover both occupations.

1. Compression

According to Patty, the immediate effects limiting the rate of compression are those of a mechanical nature. If compression is too rapid, dizziness, nausea, disorientation, and/or pain in the ears may be experienced. Wherever there is a gas-tissue interface within the body, such as the sinuses, lungs and middle ear, there can be problems during compression caused by unequal distribution of pressure. This condition is called barotrauma, or "squeeze." If the pressure imbalance is great enough, pain, ruptured blood vessels, and potentially harmful tissue damage can occur. If a person is not adept at opening his or her eustachian tubes, or if the eustachian tube is otherwise obstructed, as by mucous, edema, or an overgrowth of tissue, equalization of pressure in the middle ear cannot take place. The increased pressure forces the eardrum inward; rupture can occur at 5 to 10 psig. Repeated barotrauma to the eardrum can lead to tinnitus and permanent hearing deficit. When sinus openings are occluded, as by an upper respiratory infection, the capillaries lining the sinuses can distend and burst, resulting in severe pain and varying degrees of trauma.

Nitrogen narcosis is generally not a problem for caisson and tunnel workers, because pressures used are not great enough to increase the partial pressure of nitrogen to the extent that it interferes with physiologic processes.

2. Decompression

Tooth fillings which leak air can be the cause of extremely painful toothaches following decompression. Air becomes trapped under the filling, and on decompression expands, resulting in pressure on the tooth nerve.

A rare but potential problem for men who have hernias is that if a gas-filled loop of the bowel should exit the hernia opening, decompression can cause profound effects on the bowel.

In a hyperbaric environment, increased gas pressure forces more gas to be dissolved in the body than occurs at atmospheric pressure. Subsequent ascent to normal air pressure causes the absorbed gas to come out of solution as bubbles, which are responsible for producing a range of adverse effects known collectively as decompression sickness. The amount of saturation of body tissues with dissolved gases depends on both duration of exposure and on the amount of pressure attained. The greater the saturation, the longer must be the period of decompression. Despite the extensive research done on preparation of decompression tables, varying degrees of decompression sickness are common. Estimates for the incidence of acute decompression sickness range from 1% to up to 26% of decompressions.

There are several manifestations of decompression sickness, including: "Bends," an acute condition which may come on any time from the end of compression to up to 12 hours later. Symptoms range from a bothersome skin itch to a vague soreness or a deep steady pain in the joints. In more severe instances, there can be CNS involvement, with such effects as numbness, weakness, abdominal pain, unconsciousness, shock, visual disturbances, nausea and vomiting, speech difficulty and dizziness. Convulsions and death can ensue; if the victim survives, he may suffer permanent loss of sphincter control and paralysis. Another form of decompression sickness can involve audio-vestibular disorders, including partial or total hearing loss, tinnitus, or a sudden severe dizziness and nausea.

In addition, compressed-air workers are subject to an increased risk of a specific kind of skeletal damage known as dysbaric osteonecrosis. This condition is thought to be the result of blockage by bubbles of nutrient blood vessels supplying bones. If the blockage lasts for 12 hours or more, all of the osteoblasts in the blocked area die. This condition may not show up on an x-ray for a period of 3-4 months. If there is a serious lesion near a joint, structural failure, which can lead to the development of degenerative arthritis, may occur. It is not known how much exposure is necessary to initiate aseptic necrosis, nor has any direct relationship between the development of the condition and a history of attacks of decompression sickness been drawn.

Tunnel and caisson workers have for years followed schedules for decompression much shorter than those of the U.S. Navy and Admiralty tables, and the incidence of osteonecrosis in these people has been high.

Ultrasonic monitoring has shown that despite the absence of overt symptoms of decompression sickness, some bubbles always exist following decompression. These have been identified as causing damage to the lining of blood vessels, as well as long-term subtle effects on various organs and on blood components.

Using the present standard decompression tables, it has been noted that in the early days of any contract, there will be a very high incidence of decompression sickness before the workers become "acclimatized". Also, any increases in the working pressure, however slight, will cause an increase in the incidence of decompression sickness.

3. Other

- Noise levels may be excessive, due to in-rushing air and pneumatic drills.
- Insufficient ventilation of decompression chambers can result in a buildup of CO_2, which can contribute to the incidence of decompression sickness.
- Contaminants in supplied air may include CO_2, CO, oxides of nitrogen, and oil vapor.
- Psychologic effects and stress, due to the inherent nature of the work.
- High temperatures and humidity can lead to heat prostration.

C. Extent of Exposure & D. Injury and Illness Statistics

	No. of Workers	Total Cases of Injury and Illness/100	Lost Workdays/ 100 Cases
Crude Petroleum and Natural Gas Workers	84,000	4.4	39
Oil and Gas Field All Workers		18.6	188.8
Oil and Gas Field Exploration Services	13,000		
Oil and Gas Field Services Not Elsewhere Classified	58,000		
Heavy Construction, except Highway and Street	400,000	19.9	127.2
Mining	-	10.2	94.7
Contract Construction	-	18.3	99.8
National Average, All Occupations	-	10.4	54.6

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PLASTICS AND RESINS MANUFACTURE

SIC No. 2821 Plastics Materials, Synthetic Resins, and Nonvulcanizable Elastomers

Establishments primarily engaged in manufacturing synthetic resins, plastics materials, and nonvulcanizable elastomers. Important products of this industry include: cellulose plastic materials; phenolic and other tar acid resins; urea and melamine resins; vinyl resins; styrene resins; alkyd resins; acrylic resins; polyethylene resins; polypropylene resins; rosin modified resins; coumarone-indene and petroleum polymer resins; and miscellaneous resins including polyamide resins, silicones, polyisobutylenes, polyesters, polycarbonate resins, acetal resins, fluorohydrocarbon resins; and casein plastics.

Acetal resins
Acetate, cellulose (plastics)
Acrylic resins
Acrylonitrile-butadiene-styrene resins
Alcohol resins, polyvinyl
Alkyd resins
Allyl resins
Butadiene copolymers, containing less than 50% butadiene
Carbohydrate plastics
Casein plastics
Cellulose nitrate resins
Cellulose propionate (plastics)
Coal tar resins
Condensation plastics
Coumarone-indene resins
Cresol-furfural resins
Cresol resins
Dicyandiamine resins
Diisocyanate resins
Elastomers, nonvulcanizable (plastics)
Epichlorohydrin bisphenol
Epichlorohydrin diphenol
Epoxy resins
Ester gum
Ethyl cellulose plastics
Ethylene-vinyl acetate resins
Nylon resins
Petroleum polymer resins
Phenol-furfural resins
Phenolic resins
Phenoxy resins
Phthalic alkyd resins
Phthalic anhydride resins
Polyacrylonitrile resins
Polyamide resins
Polycarbonate resins
Polyesters
Polyethylene resins
Polyhexamethylenediamine adipamide resins
Polyisobutylenes
Polymerization plastics, except fibers
Polypropylene resins
Polystyrene resins
Polyurethane resins
Polyvinyl chloride resins
Polyvinyl halide resins
Polyvinyl resins
Protein plastics
Pyroxylin
Resins, phenolic
Resins, synthetic: coal tar and non-coal tar
Rosin modified resins
Silicone fluid solution (fluid for sonar transducers)
Silicone resins

Fluorohydrocarbon resins
Ion exchange resins
Ionomer resins
Isobutylene polymers
Lignin plastics
Melamine resins
Methyl acrylate resins
Methyl cellulose plastics
Methyl methacrylate resins
Molding compounds, plastics
Nitrocellulose plastics (pyroxylin)
Soybean plastics
Styrene resins
Styrene-acrylonitrile resins
Tar acid resins
Urea resins
Vinyl resins

A. Description of Process

Plastics are long-chain polymers based on natural or synthetic organic molecules. Hundreds of different polymers, with widely varying properties, can be made, but only about twenty types make up at least 90 percent of the total world output. Plastics fall into two main categories:

1. Thermosetting plastics are materials which are fully polymerized when heated and shaped into a mechanical constriction leading to a form which it retains on consolidation and cooling and which cannot be reshaped later by the application of heat. Among these, the most important are phenol-formaldehyde and urea formaldehyde. Epoxies, unsaturated polyesters, and polyurethanes are also included in this class.

2. Thermoplastics are polymers which are brought by heat to a plastic state and can be softened repeatedly by the reapplication of heat. Most of these are produced by the additional polymerization of vinyl polymers such as ethylene, vinyl chloride, styrene, or propylene. Benzoyl peroxide, azo-bisis obutyronitrile, and potassium peroxysulfate are the principal initiators. This is by far the larger group, and it is growing at a much faster pace than the thermosetting plastics.

The diversity of the thermoplastics industry is tremendous. One monomer, like Vinyl Chloride (VC), can be blended with a variety of accelerators, fillers, pigments, stabilizers, and other materials to produce the polymer, Polyvinyl Chloride (PVC), which is used in a variety of products such as tape cassettes, insulation for cables, tubing, upholstery, footwear, tools, and bottles.

The polymerization process from the monomer, Vinyl Chloride, to the polymer, Polyvinyl Chloride (PVC), is itself very complex. There are four types of polymerization processes for PVC (suspension, bulk, emulsion, and solution) which utilize such diverse initiating agents as lauryl peroxide, isoprpyl peroxy dicarbonate, azobisisobutyronitrile, benzoyl peroxide, and aminoethanols. The stabilizers used in the PVC process include Organo-tin compounds, Organo-phosphite chelators, expoxidized resins, barium salts, zinc and calcium salts, etc. The fillers used are carbon black, wood fibers, calcium carbonate, asbestos, diatomaceous earth, etc. There are more than 227 monomers, polymers, catalysts, dispersants, emulsifying agents, surfactants, and organic solvents used or produced in this industry.

The manufacture of plastics from polymerizable material entails the mixing of the polymer with additives. Though there are a great variety of machines employed for this purpose, where powders are being mixed, high speed mixers are used and where plastic masses are being used large batch-type mixers (Bawbury types) are used.

Some of the additives required by the industry can be categorized as follows:

- Plasticizers - generally esters of low volatility (e.g., phthalates, aliphatic esters, epoxy esters, phosphate esters).
- Antioxidants - organic chemicals to protect against thermal decomposition during processing (p-phenylene diamines, amino compounds, phenolic compounds).
- Stabilizers - inorganic and organic chemicals to protect against degradation from radiant energy (phosphates, zinc oxide, stearic oxide, etc.).
- Fillers - used to reduce costs and to confer special properties, such as opacity, hardness and ultra violet light resistance (diatomaceous earth, amorphous fused silica).

B. Hazards

The general physical hazards of handling a high volume of plastic chemicals include:

- splashes of chemicals on skin and especially in the eyes,
- hand and arm injuries involved with handling drums, valves, and piping,
- unexpected sudden release of pressure in pipelines containing chemicals,
- entry into reactors where there may be high vapor concentrations,
- fire and explosion hazards,
- burns from contact with equipment,
- and falls from slipping where chemicals have been spilled on floors.

Toxicity data on the plastics and resin manufacturing chemicals can be evaluated in four classes: (1) plasticizers (2) antioxidants (3) stabilizers (4) fillers.

Plasticizers

The major group of plasticizers are the phthalate esters where in 1974, 1,207 million pounds were produced.

- Phthalate esters - Reports have indicated that the phthalates may affect blood components in the human and guinea pig and exert a teratogenic effect upon chicks and rats. Major questions relating to possible hazards of phthalates to humans are mostly concerned with subtle or delayed effects upon health such as teratogenic effects, rather than acute or dramatic effects. There are no specific health hazards identified as yet.

Acute Toxicity of Some
Phthalate Esters

Compound	Acute ip LD50 in Male ICR Mice LD50 (g/kg)
Dimethyl phthalate	3.98
Diethyl phthalate	3.22
Di-n-butyl phthalate	3.57
Diisobutyl phthalate	3.99
Di-n-octyl phthalate (DOP)	65.70

T.L.V. Diethylphthalate (DEP) - ACGIH (1976) 5 mg/cu m

Antioxidants

Two of the major groups of antioxidants in synthetic manufacture are Phenylenediamines and Phenolics.

- Phenylenediamines - systemic toxicity with exposure to these compounds is not recognizable. However, they may cause contact dermatitis and possibly bronchial asthma. Such asthma ceases promptly with complete withdrawal of exposure.

Rats-oral - LDLO 100mg/kg
Rats-i.p. - LDLO 50 mg/kg
Rats-scu - LDLO 170 mg/kg
Dogs-scu - LDLO 100 mg/kg
Man -i.v.n. - LDLO 17 mg/kg

U.S. Occupational Standard (air) for p-phenylene diamine: TWA 100 yg/cu m (skin)

- Phenolics - The main hazard with the Phenolic group stems from exposure to phenol which may cause dermatitis and changes in the mucous membrane (simple irritation or sensitization).

Rats-skin - LD50 699 mg/kg
Rats-i.p. - LD50 250 mg/kg
Mice-s.g. - LD50 344 mg/kg

U.S. Occupational Standard (air) for phenol:
TWA 5 ppm. (skin)

Stabilizers - Phosphites are a major class of stabilizers. Triphenyl phosphite is a commonly used stabilizer in this group.

- Studies with rats showed LD50's with oral application to be 1.6-3.2 g/kg. Tremors, diarrhea, and vasodiatation by all routes was caused during this experiment.
- Skin and eye irritation was observed in guinea pigs exposed to 1.6-3.2 g/kg.

U.S. Occupational Standard air: TWA 1 mg/cu m

Fillers

Diatomaceous Earth - Diatomaceous Earth injected into animals caused progressive nodular fibrosis; however, men exposed to the dust showed no evidence of serious lung pathology

- Guinea pigs exposed for 37 to 50 weeks to uncalcined diatomaceous earth at an average concentration of 60 mg/cu m exhibited extensive gross and microscopic lung changes, but no fibrosis.
- Silicosis was induced in rats by the intratrachial injection of diatomaceous earth at a concentration of 0.075 to 0.13 mg/cu m.

1975 ACGIH T.L.V. -20 mppcf (3 mg/cu m total dust)
1976 ACGIH T.L.V. -1.5 mg/cu m (respirable mass)

C. Extent of Exposure

1. Plasticizers - 1,000,000
2. Number of establishments - 461
   Number of employees, total - 161,900
   Number of production workers - 116,000
   Number of support personnel - 45,900

Future - The synthetic plastic and resin industry has expanded rapidly since the end of World War II. Most modern processes are closed systems so that the extent of ambient exposure to the synthetic processing chemicals is relatively contained. Higher volumes of plastic materials can be expected in this industry in the future.

D. Injury and Illness Rates

	Total Cases of Injury and Illness/100	Lost Workdays/ 100 Cases
Plastics and resin manufacture	10.7	58
Mining	10.2	94.7
Contract construction	18.3	99.8
National average, all occupations	10.4	54.6

E. Summary

Plastics and Resin Manufacture
(SIC No. 2821)

	Health Hazard
Plasticizers	Possible blood effect
Antioxidants	Possible dermatitis
Stabilizers	Non-toxic (generally)
Fillers	Possible dust hazards

Extent of Exposure

Number of establishments -	461
Number of employees -	161,900
Number of production workers -	116,000
Support personnel -	45,900

Economic Trend - increasing since World War II

Information Gaps - it would be difficult to evaluate the plastic manufacturing without a complete evaluation of all the major components in the polymerization process. Some component chemicals with high toxicity may be used in one of the many processes to a lesser extent than a high volume monomer or accelerator that has relatively low toxic effect levels. The chemicals with very toxic effect levels must be evaluated individually.

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ENTERING CONFINED SPACES

SIC No. - None

A. Description

"Entering confined spaces" is a generalized term for a situation that can occur in a variety of workplaces. There is no standardized definition, but in general, a space having a relatively small volume, with poor natural ventilation and a small or remote entry and egress opening can be considered a "confined space." Industries having the greatest potential for such a situation are those that use vats, tanks, drums, reaction vessels, silos, pits, barrels, chambers, or other large vessels as pieces of equipment during manufacturing processes or for storage of liquids, solids, or gases. Other confined spaces include those of conduits, pipes, ventilation ducts, etc. Most large companies follow safety and workplace practices guidelines developed by trade unions or state safety boards, including recommendations as to use of monitoring equipment, ventilation, protective clothing and respirators, communications, a "buddy system," etc.

B. Hazards

Hazards which may be encountered cover a broad range of chemical and physical agents. Potentially toxic levels of substances which may be present include the originally contained material or its decomposition products, such as hydrogen sulfide evolution from sewage; toxic substances generated due to the inadvertent mixture of wrong formulations; and compounds used in the operation being performed, such as cleaning solvents. Oxygen deficiency, as may occur due to fermentation processes or to rusting of iron-containing steel walls, can be an unexpected and serious hazard.

Other potential hazards include:

- Electrocution
- Vibration
- Excessive heat and humidity
- Scalds or burns
- Noise
- Psychologic trauma and stress
- Hazards present in the space itself, such as lack of lighting, low-hanging fixtures, uneven flooring, and unguarded mechanical parts

C. Extent of Exposure & D. Injury and Illness Statistics

Usually, the reason for being in a confined space is for purposes of performing a non-routine function, such as repair, cleaning, or painting. Repair and maintenance personnel are therefore those most likely to be affected. However, because of the generalized and undefined nature of this hazard, a reasonable estimation of numbers of workers who may be exposed is nearly impossible. Potentially anyone can be exposed.

Industries where "confined spaces" are integral to the manufacturing process include:

Leather tanneries
Pulp and paper mills
Any chemical-formulating or chemical-products manufacturing plants
Petroleum refineries
Dye operations
Paint and allied products manufacture and application
Synthetic textile manufacture
Fertilizer plants
Sewage treatment
Food processing

This list is included in order to give an idea of the wide range of workplaces in which the situation of having to enter a "confined space" may occur; it is not meant to be comprehensive.

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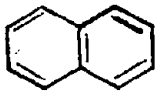
SINGLE CHEMICAL HAZARDS

Naphthalene $C_{10}H_8$

Chemical Structure



Chemical Abstract Service Number

000091203

Synonyms

moth balls, moth flakes, Naftalen (Polish), Naphthene, Naphthaline, Naphthalin, white tar, tar camphor

Chemical and Physical Properties

Naphthalene is slightly soluble in water and is soluble in many organic solvents. It forms azeotropes (constant boiling mixtures) with various compounds and is a good solvent for a wide variety of compounds. It has a characteristic odor. Other chemical and physical properties are:

molecular weight	128.18	
melting point	80.29°C	
boiling point	217.95°C	
d_4^{30}	1.01813	
n_o^{25}	1.5898	
flash point (closed cup)	79°C	
ignition temperature	526°C	
flammable limits, vol %	upper 5.9	lower 0.9
heat of fusion, cal/g-mole	4536	
heat of formation at 25°C, cal/g-mole		
solid	18.75	
liquid	23.02	
gaseous	36.25	

Consumption/Uses

The major uses of naphthalene are as a raw material for phthalic anhydride production and for the synthesis of its major chemical derivatives, 1-naphthyl-N-methyl carbamate and beta-naphthol. In addition to its use in the production of these compounds, naphthalene is also used to synthesize

other carbamate insecticides. It is used to produce a large number of intermediates for synthetic organic dyes, plasticizers, and pharmaceuticals. Naphthalene is also used as a synthetic tanning agent, a surface-active agent, and a moth repellant. It should be noted that there has been a shift from naphthalene to ortho-xylene as the preferred raw material for phthalic anhydride production and that this trend is expected to continue. Estimated consumption of naphthalene in 1975 is presented in the following table:

Use	Millions of Pounds
phthalic anhydride	220
1-naphthyl-N-methyl carbonate	72-78
Beta-naphthol	33-35
synthetic tanning agents	26
moth repellant	11
surface-active agents	4-5
miscellaneous and exports	10

Production

Naphthalene is produced from both coal tar and petroleum distillation. In the past, coal tar distillation was the exclusive source of naphthalene, and it will continue to be the dominant source. The petroleum distillation industry became involved in naphthalene production in response to demands of supply and product quality posed by the phthalic anhydride industry. With the shift to ortho-xylene as the preferred raw material (69% of phthalic anhydride was synthesized from ortho-xylene in 1975), the growth outlook for naphthalene production is dim and demands for this compound have dropped. A concomitant drop in petronaphthalene production has been observed. Other deterrents to increased naphthalene production include the current high cost and limited availability of energy. The fuel value of coal tar products is beginning to override the significance of their other uses. Although in the future naphthalene may become available from coal gasification and/or liquefaction plants at low cost, this factor is not expected to rise to significance or to be reflected in production levels until the mid-1980s. In 1973, 601 million pounds of naphthalene were produced; 360 million pounds came from coal tar distillation, and 241 million pounds came from petroleum distillation. In 1975, 143 million pounds of naphthalene were produced from petroleum distillation. Total production figures past 1973 are unavailable due to lack of statistics on naphthalene production from the coal tar industry.

There are currently 6 producers of chemical naphthalene and 5 producers of crude naphthalene for upgrading. A total of 5 of these manufacturers have been identified as producing naphthalene from coal tar, while 2 produce it from petroleum. There are approximately 40 distributors of various forms of naphthalene for various uses. Current production capacities are:

	Millions of lbs	Percent of Total
Petroleum	240	39%
Coal tar	466	61%
Total	756	100%

Toxicity

Animal

LD50 Values:

Rat	oral	1780 mg/kg	
Rat	subcutaneous	3500 mg/kg	TDLo, neoplasm, 98d intermitt
Mouse	intraperitoneal	150 mg/kg	(LDLo)

Human

Naphthalene vapors act as an eye irritant. Toxic reactions occur after ingestion of large doses, inhalation of vapors, or skin absorption. A reported minimum lethal dose was 100 mg/kg in a child. Systemic effects include nausea, vomiting, headache, diaphoresis, hemolytic anemia, hematuria, fever, and profuse perspiration. Acute exposures can cause hapatic necrosis, convulsions, coma, and optic neuritis. Other reported effects include contact dermatitis from primary irritation and/or allergic hypersensitivity. Although chronic toxicity data is largely unavailable, it has been reported that prolonged exposure at high concentrations causes opacity of the lens.

Occupational Exposure

NIOSH estimates that 50-100,000 workers are potentially exposed to naphthalene each year. Occupations in which workers may be exposed to naphthalene include the following:

- o-aminobenzoic acid makers
- dye intermediate makers
- Beta-naphthol makers
- smokeless powder makers
- hydronaphthalene makers
- insecticide workers
- lampblack makers
- moth repellant workers
- phthalic anhydride makers
- scintillation counter makers
- soil treaters
- textile chemical makers
- celluloid makers
- fumigant workers
- hydronaphthalene makers
- fungicide makers
- coal tar workers
- cutting fluid workers
- dye chemical makers
- lubricant workers
- naphthalene workers
- resin makers
- tannery workers

Current Standards

The U.S. Occupational Standard for naphthalene is 10 ppm, as an 8-hour time-weighted average in air. The ACGIH Threshold Limit Value is also 10 ppm. Several foreign countries also have set standards for naphthalene. These are maximum allowable concentrations and are listed below:

Foreign Standards for Naphthalene

Country	MAC
Germany	10 ppm
Bulgaria	20 mg/m^3
Hungary	20 mg/m^3
Poland	20 mg/m^3
Rumania	20 mg/m^3
U.S.S.R.	20 mg/m^3
Yugoslavia	50 mg/m^3; 10 ppm

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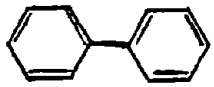
Diphenyl $C_{12}H_{10}$

Chemical Structure



Chemical Abstract Service Number

000092524

Synonyms

phenylbenzene, biphenyl, bibenzene, xenene

Chemical and Physical Properties

Diphenyl is a white or slightly yellow crystalline solid which is stable and resistant to thermal decomposition and radiation degradation. Its other properties are:

molecular weight	154.22
melting point	69.2°C
freezing point, commercial product	68.5 - 69.4°C
boiling point @ 760 mm	255°C
d_4^{20}	1.041
density	0.314 g/cm^3
flash point	113°C
fire point	123°C
ignition temperature of dust cloud	650°C

Consumption/Uses

The largest outlet for diphenyl is as a raw material for the synthesis of its derivatives. Its major direct use is as a heat-transfer fluid. Diphenyl is also used as a dye carrier, deodorant and mildew retardant, and as a paper impregnant for citrus fruit wrappers. Consumption figures are unavailable.

Production

Diphenyl has been produced since 1926 and is manufactured by the thermal degradation or partial oxidation of benzene. In the future, there may be a trend toward the production of diphenyl by processes used in petroleum refineries to produce aromatic hydrocarbons, particularly the hydrodealkylation operations used in naphthalene synthesis. There are two major and five minor manufacturers of diphenyl, but no published production statistics are available. Manufacturers of this compound declined to impart information on production, it being proprietary in nature.

Toxicity

Animal

Diphenyl has a relatively low order of toxicity.

LD50 Values:

Rat	oral	3280 mg/kg
Rabbit	oral	2400 mg/kg
Mouse	subcutaneous	46 mg/kg (TDLo)
Rabbit	skin	2500 mg/kg

Human

The primary toxic effect of diphenyl in humans is irritation from vapors. The lowest published toxic exposure level is 4400 mg/cu m. Diphenyl acts as a respiratory tract irritant.

Occupational Exposure

NIOSH estimates that 5-10,000 workers are potentially exposed to diphenyl each year.

Current Standards

The U.S. Occupational Standard for diphenyl is expressed as a 0.2 ppm (approximately 1 mg/cu m) 8-hour, time-weighted average. The ACGIH threshold limit value is also set at 0.2 ppm to prevent irritation and injury to the respiratory passages. The German MAC is the same as the ACGIH Threshold Limit Value.

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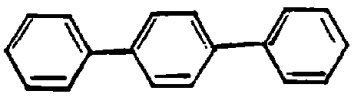
Terphenyl $C_{18}H_{14}$

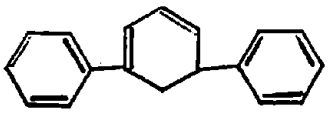
Chemical Structure

Chemical Abstract Service Number

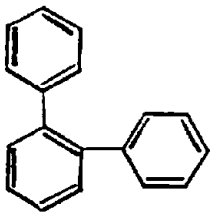
000092944



p-terphenyl



m-terphenyl



o-terphenyl

Synonyms

diphenylbenzene, triphenyl, p-terphenyl, o-terphenyl, m-terphenyl, Santowax O, Santowax M, Santowax P, Santowax R, phenylbiphenyl, 1,4-diphenylbenzene, triphenylbenzene, 4-diphenylbenzene

Chemical and Physical Properties

Pure terphenyl is a white, crystalline solid. The commercial grades are light yellow. All three isomers (para, ortho, and meta) are unusually stable toward heat. The properties of the terphenyls are:

	ortho	meta	para
molecular weight	230.31	230.31	230.31
boiling point (760 mm)	332°C	365°C	385°C
melting point	58°C	89°C	207°C
flash point	171°C	207°C	210°C
fire point	193°C	229°C	238°C
density of liquid 200°F	1.022 g/ml	1.039 g/ml	solid
vapor pressure (psia) 200°F	0.0017	0.00024	-

Consumption/Uses

Terphenyl is used primarily as a heat storage and heat transfer agent. It is also used as a high-temperature lubricant, a constituent of waxes and polishes, and as a plasticizer for resin-bodied paints. A possible emerging use of terphenyl is as a coolant or coolant-modifier for nuclear power reactors, but there are no recent data which would indicate that this possibility has become a reality. Terphenyl consumption figures are unavailable.

Production

Production data on terphenyl are somewhat contradictory. In 1971, there were 2 producers of terphenyl listed in the Directory of Chemical Producers. In 1976, this resource had no listings for terphenyl, yet Chem Sources - USA listed approximately 24 producers and distributors of this compound. A representative of Monsanto, the major manufacturer of terphenyl in 1971, stated that this company had stopped production of all terphenyls except for HB 40, a partially hydrogenated terphenyl, in May of 1973. A representative of DOW Chemical Company, the only other producer of terphenyl in 1971, was unable to provide any information on its production or discontinuance of production. Published poundage statistics are unavailable.

Toxicity

Animal

The lowest published lethal dose of p-terphenyl is an oral dose of 500 mg/kg in rats. The lowest published toxic dose of m-terphenyl is a subcutaneous dose of 1,400 mg/kg in mice.

Human

The primary toxic effect of terphenyl vapors is as an irritant, but it has a low order of toxicity in humans.

Occupational Exposure

NIOSH estimates that fewer than 5,000 workers are exposed to terphenyl per year.

Current Standards

The current U.S. Occupational tandard for p-terphenyl is a ceiling concentration of 1 ppm in air. The ACGIH Threshold Limit Value is the same. There are no foreign standards for this compound.

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Ammonium Nitrate

Chemical Structure

NH_4NO_3

Chemical Abstract Service Number

006484522

Synonyms

ammonium salt of nitric acid

Chemical and Physical Properties

Ammonium nitrate is an odorless, transparent, white crystalline solid. It is very soluble in water, and aqueous solutions of ammonium nitrate are frequently handled in commercial operations. Its other properties are:

molecular weight		80.06
melting point	approximately	155°C
boiling point	approximately	180°C
d_4^{20}		1.725
vapor pressure (saturated solution)		
10°C		6.45 mmHg
40°C		29.2 mmHg
freezing point		169.6°C
specific heat (64% aqueous solution)		0.6102 cal/mole

Consumption/Usage

In the period before, during, and immediately after World War II, ammonium nitrate was used primarily in its solid form as a principal constituent of explosives for military and civilian use.

Currently, the most significant use of ammonium nitrate is as the major constituent of both liquid and solid fertilizers. It continues to be used as the principal component of most nonmilitary, industrial explosives and blasting agents used in coal, metal and nonmetal mining, and in quarrying, railway construction, and general construction. It is also used in the production of the anesthetic, nitrous oxide.

There is some indication that the ammonium nitrate component of the chemical nitrogen business is approaching peak maturity after the period of steady and substantial growth following World War II. This trend may be

particularly significant and most conspicuous in the area of solid ammonium nitrate demand, for it appears that demand for liquid ammonium nitrate may actually be growing. Within the fertilizer market, demand for solid ammonium nitrate products is expected to decline from 3,957 thousand short tons in 1974 to 3,545-3,780 thousand short tons in 1980, while demand for the liquid product is expected to increase at an average annual rate of approximately 2.3-3.5% to a total of 3,550-3,685 thousand short tons in 1980. It has also been predicted that direct application of liquid ammonium nitrate for use in nitrogen solutions will increase at an average annual rate of 1.5-3.0% until 1980. During this same period, direct application of solid ammonium nitrate will decrease at a rate of 0.5-1.2% per year. It should be noted that although demand may decline, positive but small growth rates are still expected in most sectors.

In the explosives and blasting agents sector of the market, increased demand for solid ammonium nitrate will be largely dependent on the demand for explosives and blasting agents within the coal industry. In 1974, this industry used 45% of all ammonium nitrate consumed in the manufacture of these products.

A future average annual growth rate of 4-6% in demand for solid ammonium nitrate in the quarrying sector is predicted based on continued demand for crushed stone as a roadbase and for use in cement and concrete. A 2.5-4.7% average annual increase in demand for ammonium nitrate in the production of nitrous oxide is predicted. This will depend to some extent, however, on the outcome of studies currently being conducted by NIOSH to evaluate the safety of this gas for female operating room personnel. There is some evidence that it may increase the incidence of birth defects and spontaneous abortions in pregnant women. A possible increase in the use of nitrous oxide as an aerosol propellant to replace fluorocarbons may also affect demand for ammonium nitrate. Ammonium nitrate consumption data and consumption trends are summarized in the tables below.

Ammonium Nitrate Consumption in 1975

Use	Thousands of Short Tons
liquid fertilizers	2,900
solid fertilizers	3,390
industrial explosives and blasting agents	1,220
nitrous oxide	20
exports	35
Total	7,565

2820

Predicted Ammonium Nitrate Consumption Trends - 1974-1980

Use	Thousands of Short Tons 1974	1980	Average Annual Growth Rate (%)
total fertilizers	7,043	7,095 - 7,465	0.1 - 1.1
liquid fertilizers	3,086	3,550 - 3,685	2.3 - 3.5
solid fertilizers	3,957	3,545 - 3,780	(-1.1) - (-1.8)
industrial explosives and blasting agents	1,213	1,488 - 1.639	3.3 - 5.0
nitrous oxide	19	22 - 25	2.5 - 4.7
total	8,275	8,605 - 9,129	0.5 - 1.6

Production

Ammonium nitrate is produced by reacting ammonia and nitric acid in the presence of water. The heat of reaction is used to evaporate the water and concentrate the reaction mixture to approximately 83-87% ammonium nitrate. To produce solid ammonium nitrate, the liquid compound is subjected to prilling, granulation, graining, crystallization, or semi-graining, depending on the product specifications required. The prilling process is the most prevalent, and it consists of evaporation of the liquid, forcing it through spray equipment at the top of a high altitude tower, and subsequent air cooling on its descent and drying. Stabilizing agents are frequently added to the ammonium nitrate and are proprietary compounds which are generally composed of boric acid, diammonium phosphate, and ammonium sulfate.

Production statistics on ammonium nitrate are somewhat conflicting. The 1976 Chem Sources - U.S.A. lists 33 producers and distributors of this compound, while the 1976 Directory of Chemical Producers (U.S.A) lists 42 producers with a combined annual capacity of 9,333 thousand short tons. In 1975, there were 7,469 thousand short tons of ammonium nitrate produced in the U.S. In 1974, total production was 7,845 thousand short tons which represented 21% of total U.S. ammonia output and 23% of total U.S. ammonia consumption. Total U.S. production capacity for 1977 is estimated to be 16,179 thousand short tons.

Toxicity

Both human and animal toxicity data on ammonium nitrate are virtually nonexistent. Ammonium nitrate has an aquatic toxicity rating of 100-1,000 ppm based on the TLm test, which makes it a Grade 1, practically nontoxic, substance. There are no established median lethal doses or minimum published lethal doses for ammonium nitrate. This compound has been used in humans as a urinary acidifier and diuretic, and it has been known to produce side-effects of acidosis and methemoglobinuria in oral doses of 6-12 g/day. The mechanism for these reactions is the conversion of the ammonium ion into urea in the body. It has been noted that nitrates used

in explosives manufacture cause red skin, papular eruptions, and severe skin irritation upon dermal contact, but it is not clear that ammonium nitrate in particular has this effect.

Survey of the available occupational and pharmocologic literature indicates that the possibility of ammonia poisoning in the course of ammonium nitrate and fertilizer manufacture represents the chief toxic effect of this compound. Such poisoning is usually acute and chiefly affects the respiratory system, although it can cause central nervous system effects and spasms at high concentrations. Respiratory effects occur at concentrations above 100 mg/cu m. The toxicity of ammonia is well-documented, and NIOSH has published a criteria document on this compound which details animal and human effects. Documentation of the effects of ammonium nitrate seems to indicate that the compound has a low order of toxicity. The effects of possible ammonia poisoning in the course of handling and manufacturing the compound could probably be circumvented by proper work practices.

Occupational Exposure/Hazards

NIOSH estimates that approximately 45,000 workers are potentially exposed to ammonium nitrate each year, and that most exposure occurs in the manufacture of fertilizers. The explosiveness of ammonium nitrate is a significant occupational hazard. Disastrous explosions ascribed to this substance have occurred in the past in Texas City and Brest.

Current Standards

There are no domestic or foreign standards for ammonium nitrate.

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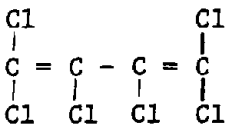
Hexachlorobutadiene C_4Cl_6

Chemical Structure



Chemical Abstract Service Number

000087683

Synonyms

1,3-hexachlorobutadiene, perchlorobutadiene

Chemical and Physical Properties

Hexachlorobutadiene is a clear, colorless liquid with a mild odor which is insoluble in water and soluble in alcohol and ether. It is nonflammable and is compatible with numerous resins. Its other properties are:

molecular weight		260.74
boiling point	approximately	215°C
melting point	approximately	-20.5°C
flash point		none
d_4^{20}		1.675
vapor pressure (100°C)		22 mm Hg

Consumption/Uses

Hexachlorobutadiene is used as a solvent for elastomers, a heat-transfer fluid, a transformer and hydraulic fluid, and a wash liquor for removing higher hydrocarbons. Consumption statistics are unavailable.

Production

Hexachlorobutadiene is derived from the manufacture of perchloroethylene, carbon tetrachloride, and trichloroethylene. It is a major component of the tarry waste from these processes. Chem Sources - USA lists only one source of hexachlorobutadiene, Henley and Company, and it is not clear whether this firm is a producer or distributor. DOW Chemical U.S.A., for example, has studied the toxicity of this compound and is a known major producer of perchloroethylene, carbon tetrachloride, and trichloroethylene. DOW does not, however, market the compound. Production figures are unavailable.

Toxicity

Animal

Animal toxicity data are summarized in the table below. It must be noted and emphasized that hexachlorobutadiene is a suspected carcinogen. Recent studies undertaken by DOW Chemical, U.S.A. showed some renal tubular neoplasms, some of which metastasized to the lungs, when fed to rats at 20 mg/kg/day of hexachlorobutadiene for 2 years. Other effects included decreased body weight gain and increased urinary excretion of coproporphyrin. Results of this and another study conducted at DOW reveal a dose-effect relationship for hexachlorobutadiene in rats. Higher doses caused severe kidney injury and cancer; intermediate doses caused reversible kidney injury; and low doses (0.2 mg/kg/day) caused no discernible ill effects.

LD50 Values

Species	Route		Dose	Duration
Rat	oral		90 mg/kg	
Rat	oral	(TDLo)	14600 mg/kg	
Mouse	oral		110 mg/kg	
Mouse	inhalation	(LCLo)	235 ppm	4 hours
Mouse	intraperitoneal	(LDLo)	32 mg/kg	
Mammal	unknown		200 mg/kg	

Human

There is a definite lack of information on human exposures to hexachlorobutadiene and the effects of this compound in humans. DOW Chemical, U.S.A. reviewed health data on employees actually or potentially exposed to hexachlorobutadiene and found no deaths or abnormalities related to this compound. Data consisted of medical histories, physical examinations, blood and serum tests, urinalyses, chest x-rays, and pulmonary function tests. Analyses of workroom air in applicable installations revealed hexachlorobutadiene levels "well below" 1 ppm.

Occupational Exposure

NIOSH has no estimates of potential worker exposure to hexachlorobutadiene.

Current Standards

There are no U.S. or foreign standards for hexachlorobutadiene.

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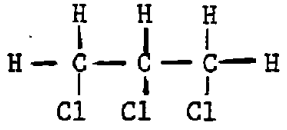
Trichloropropane $C_3H_5Cl_3$

Chemical Structure



Chemical Abstract Service Number

000096184

Synonyms

glycerol trichlorohydrin, allyl trichloride, 1,2,3-trichloropropane

Chemical and Physical Properties

Trichloropropane is a colorless liquid which is slightly soluble in water. It dissolves oils, fats, waxes, chlorinated rubber, and numerous resins. It is combustible. Its other properties are:

molecular weight	147.43
boiling point (760 mm)	156.85°C
melting point	-14.7°C
d_4^{20}	1.3889
vapor pressure (25°C)	3.59 mm Hg
vapor density (air=1)	5.0
ignition temperature	194°C
flash point	180°C

Consumption/Uses

Trichloropropane is used as a paint and varnish remover, a solvent, and a degreasing agent. Consumption statistics are unavailable.

Production

Trichloropropane is synthesized by the chlorination of propylene. There are 17 producers and distributors of this compound, with DOW Chemical Company and Shepherd Chemical Company listed as the major sources. Production figures are unavailable.

Toxicity

Animal

Animal exposure data are presented in the table below. Liver and kidney congestion and liver, kidney, and heart lesions have been noted in experimental animals.

Species	Route	Dose	Duration	Effect
Rat	oral	320 mg/kg		LD50
Rat	inhalation	1000 ppm	4 hours	LCLo
Dog	oral	200 mg/kg		LDLo
Rabbit	skin	1770 mg/kg		LD50

Human

Trichloropropane is highly toxic by inhalation and moderately toxic by skin absorption. It is a local irritant and produces a number of unpleasant sensory effects. Silverman et al (1946) exposed human subjects to trichloropropane at 100 ppm. All subjects found this to be an objectionable level of exposure, and all reported eye and throat irritation as well as an unpleasant odor.

Occupational Exposure

NIOSH estimates that fewer than 5,000 workers are potentially exposed to trichloropropane per year.

Current Standards

Country	Maximum Allowable Concentration
U.S.A., OSHA, ACGIH (TLV)	50 ppm (300 mg/cu m) air
Rumania	100 mg/cu m
Yugoslavia	50 ppm (300 mg/cu m)
U.S.S.R.	2 mg/cu m

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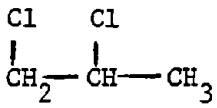
Dichloropropane $C_3H_6Cl_2$

Chemical Structure	Chemical Abstract Service Number
	000078875

Synonyms

propylene dichloride, 1,2-dichloropropane

Chemical and Physical Properties

Dichloropropane is a colorless, stable liquid, slightly soluble in water, and with a chloroform-like odor. It is soluble in alcohol and ethyl ether. Its other properties are:

molecular weight	113.0
boiling point (760 mm)	96.8°C
melting point	-100.44°C
freezing point	-100°C
d_4^{20}	1.1560
vapor pressure (25°)	53.0 mm
vapor density (air=1)	3.9
flash point	16°C
ignition temperature	557.2°C

Consumption/Uses

Dichloropropane is used as a chemical intermediate in perchloroethylene and carbon tetrachloride synthesis and as a lead scavenger for antiknock fluids. It is also used as a solvent for fats, oils, waxes, gums, and resins, and in solvent mixtures for cellulose esters and ethers. Other applications include the use of dichloropropane as a fumigant, a scouring compound, and a metal degreasing agent. Consumption statistics are unavailable, as the producers of perchloroethylene and carbon tetrachloride, who are the major users of this compound, use varied methods and do not provide breakdowns.

Production

Dichloropropane is produced by the chlorination of propylene and is the chief byproduct of the chlorohydrination of propylene. There are

four major producers of dichloropropane, with a combined annual production capacity of 50 million pounds, and five distributors. Actual production figures are unavailable. There are 14 producers and/or distributors of this compound.

Toxicity

Animal

Animal toxicity data is presented in the table below. It has been reported that dichloropropane causes histopathologic changes in the kidneys, liver and adrenal glands of experimental animals after chronic exposures at concentrations of 1000 ppm or more. Liver, kidney, and cardiac degeneration have also been observed. Hepatomas were found in some mice. Dichloropropane can also cause central nervous system depression and has produced injury in experimental animals after repeated feeding of low doses.

LD50 Values

Species	Route	Dose	Duration
Rat	oral	1900 mg/kg	
Rat	inhalation (LCLo)	2000 ppm	4 hours
Mouse	oral	860 mg/kg	
Dog	oral (LDLo)	5000 mg/kg	
Rabbit	skin	8750 mg/kg	
Guinea Pig	oral	2000 mg/kg	

Human

Dichloropropane affects the central nervous system, liver, kidneys, skin, and eyes. Skin irritation is mild, and short contacts can have no ill effects. Dichloropropane causes pain and irritation when splashed into the eyes, but does not produce serious or permanent injury.

Occupational Exposure

NIOSH estimates that 1 million workers may be potentially exposed to dichloropropane each year.

Current Standards

Country	Maximum Allowable Concentration
U.S.A., OSHA, ACGIH (TLV)	75 ppm (350 mg/cu m)
Finland	75 ppm (350 mg/cu m)
Germany	75 ppm (350 mg/cu m)
Poland	50 mg/cu m
Rumania	30 mg/cu m
Yugoslavia	75 ppm (350 mg/cu m)

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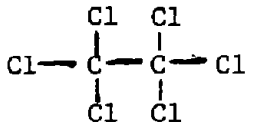
Hexachloroethane CCl_3CCl_3

Chemical Structure



Chemical Abstract Service Number

000067721

Synonyms

perchloroethane, carbon hexachloride, avlothane, ethane hexachloride, 1,1,1,2,2,2-hexachloroethane

Chemical and Physical Properties

At ordinary temperatures, hexachloroethane is a white, crystalline solid with a camphor-like odor. It is insoluble in water but soluble in alcohol and ether. It exists in 3 crystalline forms which are stable over different temperature ranges. Its other properties are:

molecular weight	236.74
melting point (sealed tube)	186.8°C
boiling point (777 mm Hg)	186°C
d_4^{20}	2.091
latent heat of vaporization	46.4 cal/g
specific heat (25°C)	0.174 cal/g
heat of combustion (solid) (20°C)	110 kcal/g-mole
heat of formation (20°C)	
macrocrystals	54
vapor	37
steam distillation point (1 atm)	99°C
vapor pressure (15°C)	0.15 mmHg

Consumption/Uses

Hexachloroethane has a relatively extensive range of widely differing applications. Its major use is in the manufacture of smoke (fog) candles and grenades. It is also used in the formulation of extreme pressure lubricants and, in small amounts, it is used to reduce the ignitability of combustible liquids. It may also be used as a moth repellant, alone or in combination with p-dichlorobenzene. Other applications are:

plasticizer for cellulose resins
anthelmitic in veterinary medicine
component of submarine paints
constituent of fungicidal and insecticidal formulations
chemical intermediate
accelerator in rubber production
retardant in fermentation processes
additive to fire-extinguisher fluids
solvent

Published consumption figures are unavailable and would be difficult to assess because of the numerous minor uses of this compound.

Production

Hexachloroethane is usually manufactured by the chlorination of tetrachloroethylene in the presence of ferric chloride at temperatures of 100-140°C. It can also be produced by the chlorination of chlorobutadiene, 1,2-dichloroethane, chloropentanes, and chloroparaffins. There are 14 producers and distributors of hexachloroethane. Production statistics are unavailable.

Toxicity

Animal

The lowest published lethal doses of hexachloroethane are 325 mg/kg intravenously in a dog, and 4000 mg/kg subcutaneously in a rabbit. Vondorf et al (1957) studied the metabolism of hexachloroethane in a rabbit, and found that a dose of 0.5 g/kg bodyweight was slowly metabolized. Over a period of 3 days, approximately 5% of the compound was excreted in the urine and 14-24% was expired in air. Metabolites found in the urine included trichloroethanol, dichloroethanol, trichloroacetic acid, dichloroacetic acid, monochloroacetic acid and oxalic acid.

Human

Hexachloroethane acts primarily as a central nervous system depressant, and in high concentrations it causes narcosis. It also may be moderately irritating to the skin, mucous membranes and liver. Irritation occurs when there is an excessive amount of hexachloroethane dust in the air, or when it is heated and vapors are formed. It should be noted that the low vapor pressure of this compound as well as its solid state minimize its inhalation hazards.

Occupational Exposure

NIOSH estimates that fewer than 5,000 workers are potentially exposed to hexachloroethane per year.

Current Standards

Country	Maximum Allowable Concentration
U.S.A., TWA, ACGIH (TLV), (skin)	1 ppm (10 mg/cu m), air
Rumania	5 mg/cu m

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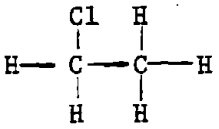
Monochloroethane C_2H_5Cl

Chemical Structure



Chemical Abstract Service Number

000075003

Synonyms

ethyl chloride, chloroethane, chloryl, ether hydrochloric, ether chloratus, narcotile, chloridum, anodynon, chelen, chlorethyl, muriatic acid

Chemical and Physical Properties

Monochloroethane is a flammable gas at ordinary temperature and pressure with a characteristic ether odor. At low temperatures or under increased pressure, it is a mobile, extremely volatile liquid which vaporizes rapidly at room temperature. Its other properties are:

molecular weight	64.52
vapor pressure (21°C)	20 mm
boiling point (760 mm)	12.27°C
melting point	-136.4°C
vapor density (air=1)	2.22
d_4^{20}	0.8978
critical temperature	186.6°C
critical pressure	52 atm
heat of combustion	316.7 kcal/g-mole
heat of formation	
liquid	31.6 kcal/g-mole
vapor	25.7 kcal/g-mole
ignition temperature	519°C
explosive limits in air	3.16-14% by vol
vapor pressure (0°C)	464 mm Hg

Consumption/Uses

The major industrial use of monochlorcethane is as an ethylating agent in the synthesis of tetraethyl lead. Approximately 90% of the monochloroethane produced in the U.S. is used in this process, and there are four major producers of tetraethyl lead with a combined capacity of 890 million pounds. Monochloroethane is also used in the manufacture of ethyl cellulose plastics and dyes, and as a pharmaceutical, solvent, alkylating agent and refrigerant.

Production

There are five manufacturers of monochloroethane with a total combined capacity of 850 million pounds, and approximately eight distributors. In 1970, 656.1 million pounds of monochloroethane were produced from ethylene and 21.9 million pounds were produced from ethyl alcohol, yielding a total of 678 million pounds. Imports are insignificant. In 1974, 660 million pounds of monochloroethane were produced.

Toxicity

Animal

Animal data on monochloroethane toxicity is sparse. In 1929, Sayers reported the effects of airborne monochloroethane vapor on guinea pigs. Exposure at a 23-24% concentration for 5-10 minutes produced loss of consciousness and some deaths. A 40 minute exposure to 15.3% monochloroethane also resulted in some deaths, while a 30 minute exposure to 9.1% monochloroethane killed no animals. Exposures to 1-5% monochloroethane for 40 minutes to 13.5 hours caused liver, kidney, and lung changes which were resolved after an unspecified period of time.

Human

Monochloroethane is readily absorbed and excreted through the lungs and primarily affects the kidney, heart, and central nervous system. It may also irritate the eyes in both the gaseous and liquid forms. Systemic and central nervous system effects of acute exposure include narcosis, dizziness, headache, eventual loss of consciousness, incoordination, and leucocytosis. Monochloroethane can potentiate adrenalin excretion, which in turn causes cardiac problems. Thus, in high doses, monochloroethane is toxic to the heart and kidneys. Rapid evaporation of the liquid from the skin can cause minor frostbite, and subcutaneous tissue edema has also been reported. The lowest published toxic concentration is 13,000 ppm. Inhalation of this concentration of monochloroethane caused slight symptoms of poisoning. In contrast, two inhalations of 40,000 ppm produced stupor, eye irritation, and stomach cramps.

Occupational Exposure

NIOSH estimates a potential occupational exposure rate of 50-100,000 workers per year. Occupations in which exposure to monochloroethane can occur include the following:

- anesthetists
- dentists
- drug makers
- ethylation workers
- ethyl cellulose makers
- ethyl chloride workers
- fat processors
- oil processors

organic chemical synthesizers	resin makers
perfume makers	sulfur processors
phosphorous processors	tetraethyl lead makers
physicians	wax makers
refrigeration workers	

Current Standards

Country	Standard
U.S.A., TWA, and ACGIH (TLV)	1000 ppm (2600 mg/cu m)
Germany, MAC	1000 ppm
Finland, MAC	1000 ppm (2600 mg/cu m)
Japan, MAC	1000 ppm (2600 mg/cu m)
United Arab Republic/Syrian Arab Republic, MAC	15 ppm
U.S.S.R., MAC	50 mg/cu m
Rumania, MAC	2000 mg/cu m
Poland, MAC	250 mg/cu m
Yugoslavia, MAC	1000 ppm (2600 mg/cu m)

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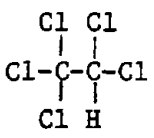
Pentachloroethane Cl_3CCHCl_2

Chemical Structure	Chemical Abstract Service Number
	000076017

Synonyms

ethane pentachloride, pentalin

Chemical and Physical Properties

Pentachloroethane is a colorless, heavy, nonflammable liquid with a sweetish odor. Its properties are:

molecular weight	202.30
melting point	-29°C
boiling point (760 mm)	162°C
specific gravity (15°C)	1.68813
n_d^t	
liquid (20°C)	1.5024
vapor (0°C)	1.00129
latent heat of vaporization (161.3°C)	44.2 cal/g
heat of formation	
liquid	45 kcal/g-mole
vapor	35 kcal/g-mole
steam distillation point (1 atm)	95.8°C
vapor pressure	
1°C	1 mm Hg
100°C	130 mm Hg

Consumption/Uses

Pentachloroethane is used in the manufacture of tetrachloroethylene and as a solvent for cellulose acetate, certain cellulose ethers, resins, and gums. It is also used as a drying agent for timber by immersion at temperatures greater than 100°C. Consumption data are unavailable.

Production

Pentachloroethane is derived from the chlorination of trichloroethylene. This is a two-step process which involves the chlorination of acetylene

to obtain tetrachloroethane and removal of hydrochloric acid by the action of alkali. There are 11 producers and distributors of pentachloroethane. Production statistics are unavailable.

Toxicity

Animal

Animal toxicity data are presented in the table below. It should be noted that cats and dogs have shown significant histopathologic changes in the liver, lungs, and kidneys after inhalation of vapors from pentachloroethane. Exposure at high concentrations leads to loss of consciousness and death.

LD50 Values

Species	Route		Dose	Duration
Rat	inhalation	(LCLo)	4238 ppm	2 hours
Mouse	inhalation	(LCLo)	35 mg/m	2 hours
Dog	oral	(LDLo)	500 mg/kg	--
Dog	intravenous	(LDLo)	100 mg/kg	--
Rabbit	subcutaneous	(LDLo)	700 mg/kg	--

Human

Pentachloroethane has a strong narcotic effect and can cause liver, lung, and kidney damage. It also acts as a local irritant to the eyes and upper respiratory tract.

Occupational Exposure

There are no estimates of occupational exposure to pentachloroethane.

Current Standards

There is no U.S. Occupational Standard or ACGIH Threshold Limit Value for pentachloroethane. Three foreign countries, however, have set standards for this compound. In 1966, Germany set the maximum allowable concentration for pentachloroethane at 5 ppm or 40 mg/cu m; Rumania has a maximum allowable concentration of 30 mg/cu m for pentachloroethane, and Yugoslavia has a maximum allowable concentration of 5 ppm or 40 mg/cu m for this compound.

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Sodium Azide NaN_3

Chemical Structure

N_aN_3

Chemical Abstract Service Number

026628228

Synonyms

NSC 3072, U 3886

Chemical and Physical Properties

Sodium azide is a stable, neutral, white crystalline solid. Its other properties are:

molecular weight	65.02
melting point	decomposes
specific gravity	1.846
solubility	
water	100 g @ 10°C
alcohol and benzole	slightly soluble

Consumption/Uses

Sodium azide is used as an explosive and as a source of hydrazoic acid. It is also used in the preparation of lead azide and pure sodium, and in some organic syntheses; Sodium azide is also used in in vitro diagnostic products and as a diluent in automatic blood cell counters. Consumption statistics were unavailable.

Production

There are 31 producers and distributors of sodium azide. Production statistics are unavailable.

Toxicity

Animal

Sodium azide is highly toxic to experimental animals. Signs observed after relatively high doses include respiratory stimulation, convulsions, depression, and death. Lower doses produce variable convulsions and consistent, prompt, transient drop in blood pressure. Other effects observed in various species include hematuria, cardiac irregularities, severe intoxication, injury to and demyelination of nerve fibers, testicular damage, blindness, and rigidity with abnormal motions.

Species	Route	Dose	Effect
Rat	oral	46 mg/kg	LDLo
Rat	intraperitoneal	30 mg/kg	LDLo
Rat	subcutaneous	35 mg/kg	LDLo
Mouse	intraperitoneal	27 mg/kg	LD50
Monkey	intravenous	12 mg/kg	LDLo
Monkey	intramuscular	10-12 mg/kg	death after 3-5 treatments

Human

Sodium azide is rapidly absorbed from the gastrointestinal tract and from injection sites. It has been administered to hypertensive patients and produces drops in blood pressure which are greater in hypertensive than in normotensive individuals. Data on human toxicity is sparse, however, Patty reported a case of dizziness, weakness, blurred vision, shortness of breath, faintness, reduction in blood pressure, and bradycardia in a chemist acidifying 10 g of sodium azide in a malfunctioning hood.

Occupational Exposure

NIOSH estimates that fewer than 5,000 workers are exposed to sodium azide per year.

Recently, NIOSH has issued an alert to hospitals and clinical laboratories on the explosive hazard of sodium azide, formulated into diluents used in conjunction with automatic blood cell counters, in plumbing systems. The alert notes that counters using these sodium azide diluents are found in over 15,000 hospitals and clinical laboratories in the U.S., and that a number of U.S. and Canadian hospitals have reported violent sodium azide-related explosions associated with automatic blood cell counters.

The NIOSH report states that sodium azide is a common preservative in many in vitro diagnostic products, and that it is found in concentrations of up to 0.1% in the diluents used with automatic blood cell counters. Sodium azide-containing waste from these machines is commonly discharged into a drain used solely for this purpose. The drain pipeline is thus bathed with solutions of sodium azide. The azide reacts with copper, lead, brass, or solder in the plumbing system forming an accumulation of lead and/or copper azide which is highly explosive. Thus, laboratory maintenance workers in general and plumbers in particular are exposed to this explosion hazard.

Bibliography - Sodium Azide

1. Kirk-Othmer (eds): Encyclopedia of Chemical Technology, ed 2. New York, Interscience Publishers, 1967

2. Patty FA (ed): Industrial Hygiene and Toxicology, ed 2 rev. New York, Interscience Publishers, 1963, vol 2, 2377 pp

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9. National Occupational Hazard Survey, National Institute of Occupational Safety and Health.

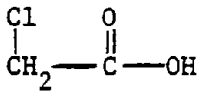
10. Christensen HE, Lugingyhl TT (eds): Registry of Toxic Effects of Chemical Substances--1976 Edition. Rockville, Maryland, US Dept of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, 1976

11. Toxline/Chemline data bases

12. NIOSH alert on sodium azide

Monochloroacetic Acid $C_2H_3ClO_2$

Chemical Structure



Chemical Abstract Service Number

000079118

Synonyms

chloroacetic acid, chloroethanoic acid, monochloroacetic acid solution

Chemical and Physical Properties

Monochloroacetic acid is a colorless or white crystalline solid which is very soluble in water and soluble in alcohol, benzene, ether, and chloroform. Its other properties are:

molecular weight	94.50
boiling point	187.85°C
melting point	63°C
d_4^{20}	1.4043
vapor pressure (23°C)	1 mm
vapor density (air=1)	3.26
n_d^{20}	1.4297

Consumption/Uses

Monochloroacetic acid is used primarily as a chemical intermediate in the synthesis of sodium carboxymethyl cellulose, and such other diverse substances as ethyl chloroacetate, glycine, synthetic caffeine, sarcosine, thioglycolic acid, and various dyes. It is also used as an herbicide. In 1968, the most recent year for which consumption figures are available in the Chemical Economics Handbook, consumption reached a level of 85 million pounds. In 1972, estimated consumption of monochloroacetic acid in sodium carboxymethyl cellulose synthesis reached 30 million pounds. A total consumption figure of 96 million pounds in 1975 is cited in Scoring of Organic Air Pollutants - Chemistry, Production and Toxicity of Selected Synthetic Organic Chemicals.

Production

Monochloroacetic acid is produced by chlorination of acetic acid in the presence of acetic anhydride, phosphorous, or sulfur. It can also be derived from the hydrolysis of trichloroethylene with 90% sulfuric acid.

There are 3 producers of monochloroacetic acid and approximately 25 distributors. The annual estimated production capacity rose from 68 million pounds in 1972 to 80 million pounds in 1976. Dow Chemical U.S.A. is the major producer, with a 45 million pound annual capacity. It should be noted that the disproportionate increase in production capacity can be explained by the closing of Monsanto's 15 million pound-per-year plant in 1972. Actual production figures have been unavailable since 1970, presumably because publication of this information would disclose Dow confidential data. In 1969, production totaled 64.2 million pounds and imports totaled 21.3 million pounds. Imports rose to 34.3 million pounds in 1973 and were at a level of 24.92 million pounds in 1975.

Toxicity

Animal

Animal toxicity data is summarized in the table below. Signs reported in various species include apathy, weight loss, narcosis, and subsequent death or complete recovery. Dalgaard-Mikkelson et al (1955) and Fuhrman et al (1955) conducted feeding studies in rate using 0.1% monochloroacetic acid in the diet and found increased levels of liver glycogen in the absence of specific lesions.

Species	Route	Dose	Effect
Rat	oral	76 mg/kg	LD50
Rat	subcutaneous	5 mg/kg	LD50
Mouse	oral	165 mg/kg	LD50
Mouse	intraperitoneal	500 mg/kg	LD
Mouse	subcutaneous	100 mg/kg	TDLo; neoplasm

Human

Monochloroacetic acid is primarily an irritant and can produce severe local skin, eye, and respiratory tract reactions. It is absorbed through the skin and is moderately toxic by inhalation of dust and vapor. It is also a disaster hazard, as it emits phosgene and chloride fumes.

Occupational Exposure

NIOSH estimates that 100-200,000 workers are potentially exposed to monochloracetic acid each year.

Current Standards

There are no U.S. or foreign standards covering monochloracetic acid.

Bibliography - Monochloroacetic Acid

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13. Mitre: Scoring of Organic Air Pollutants--Chemistry, Production and Toxicity of Selected Synthetic Organic Chemicals.

Pyrolysis Fuel

Synonyms

quench oil, A and B Dripolene

Chemical and Physical Properties

Pyrolysis fuel is a conglomerate mixture of different organic substances such as polycyclic aromatic hydrocarbons, dicyclopentadiene, naphthalene, and substituted naphthalene. It is a high-boiling, tarry residue which is formed during the cracking of naphtha and liquid petroleum gas to make ethylene, propylene, butadiene, and other olefins. Its chemical structure and physical properties vary from day to day within the same company and from company to company. Physicochemical properties also vary as a function of feed stock, cracking conditions, steam pressure, and temperature. The chemical constituents of this substance have not been defined, and its properties have not been delineated.

Consumption/Uses

The only known market for pyrolysis fuel consists of a few small chemical companies which recover rare and unusual extraneous chemicals from pyrolysis fuel in small amounts. The cost of such recovery is very high. Almost all pyrolysis fuel produced is consumed by the producers as a supplemental fuel. Union Carbide, the only known producer/user of pyrolysis fuel, was unable to provide any information on consumption rates.

Production

Pyrolysis fuel is produced as a by-product of the cracking of naphtha and liquefied petroleum gas during ofefins manufacture. Thus, producers of olefins are also producers of pyrolysis fuel. The percentage yield of pyrolysis fuel per unit of feed stock cracked is unknown, although it is known that it fluctuates widely. According to Union Carbide, the oil industry also produces a similar by-product from the catalytic cracking of oils which is metered, in small quantities, into fuel oils. Several major oil companies, most notably Exxon and Sun Oil Company, failed to substantiate this fact in personal communications. The yield of pyrolysis fuel from all cracking operations is highly variable, depending on both process and feed stock characteristics.

There are no published production statistics for pyrolysis fuel. Since no manufacturing statistics on percentage yields and conversion factors are available, it is impossible to estimate pyrolysis fuel production from olefins and oil manufacture figures.

Toxicity

Animal

Union Carbide has sponsored studies at the Carnegie-Mellon Institute of Research which show pyrolysis fuel to be carcinogenic in mice. Two groups of 40 male C3H/HeJ mice were painted three times weekly with undiluted quench oil from Union Carbide's Ponce, Puerto Rico, plant or with A and B Dripolene from the South Charleston, West Virginia, olefins plant. Results showed that the Ponce quench oil produced 94% tumor and cancer indices in less than 15 months of treatment, with an average latency of 10.3 months for tumors and 12.1 months for malignancies. Tumors were skin tumors, and malignancies were carcinomas with some metastases into the thoracic viscera. A and B Dripolene produced a 100% tumor index and a 97.2% cancer index in less than 15 months of treatment, with average latencies of 10.2 months for tumors and 12.2 months for cancer. Tumors were of the same type produced by quench oil, and some metastases into the thoracic viscera were also observed.

Other studies on pyrolysis fuel are unavailable.

Human

The only known effects of pyrolysis fuel on humans at this time are severe skin and eye irritation from dermal contact and exposure to vapors. The agent or agents in pyrolysis fuel responsible for these effects have not been identified.

Occupational Exposure

There are no estimates of potential occupational exposure to pyrolysis fuel. Such exposure might reasonably be expected to be quite widespread. Olefins production workers, petroleum production workers, fuel oil handlers, and, to a much lesser extent, chemical producers may be potentially identified as risk groups. Characterization of groups being at risk, however will depend on further definition of pyrolysis fuel itself, the processes involved in its production, and its uses.

Current Standards

There are no current or previous domestic or foreign standards for pyrolysis fuel.

Bibliography

1. Personal communication with Dr. Carl U. Dernehl, Associate Corporate Medical Director, Union Carbide Corporation, New York, New York

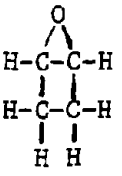
2. NIOSH Alert on pyrolysis fuel

3. Union Carbide press release

4. Report of Carnegie-Mellon Institute of Research

Tetrahydrofuran C_4H_6O

Chemical Structure



Chemical Abstract Service Number

000109999

Synonyms

1,4-epoxybutane, butylene oxide, furanidine, cyclotetramethyleneoxide, hydrofuran, oxolane, oxacyclopentane, tetramethylene oxide

Chemical and Physical Properties

Tetrahydrofuran is a colorless liquid with an ether-like odor. It is miscible with water and most organic solvents. Its other properties are:

molecular weight	72.10
boiling point (760mm)	66° C
melting point	-85.68° C
vapor density (air=1)	2.5
vapor pressure (20° C)	143 mm
n_d^{20}	1.4070
d_4^{20}	0.8892
freezing point	-17.2° C

Consumption/Uses

The primary use of tetrahydrofuran is as a solvent to dissolve synthetic resins, particularly polyvinyl chloride and vinylidene chloride copolymers. It is also used to cast polyvinyl chloride films, to coat substrates with vinyl and vinylidene chloride, and to solubilize adhesives based on or containing polyvinyl chloride resins. Further uses include raw material for the synthesis of several substances, solvent for other high polymers, and fabrication of food transportation and storage items. An emerging use of tetrahydrofuran is in vinyl adhesives for joining polyvinyl chloride pipe parts. Approximately 82 million pounds of tetrahydrofuran were consumed in 1973, and an increase of 7% per year since that time has been predicted.

Production

Tetrahydrofuran is produced by the decarbonylation of furfural to furan in the presence of steam and a zinc-chromium-molybdenum catalyst followed by catalytic hydrogenation to tetrahydrofuran. Before 1969, all domestic tetrahydrofuran was produced from furfural; currently, some

tetrahydrofuran is also produced from acetylene and formaldehyde. In 1973, only 8 million pounds were produced from furfural. Total production of tetrahydrofuran was estimated at 90 million pounds in 1975. Both production and consumption data are expected to remain relatively stable. There are 2 major producers of this compound and approximately 30 distributors and/or minor producers.

Toxicity

Animal

The lowest published lethal doses of tetrahydrofuran are an oral dose of 3000 mg/kg in a rat and an intraperitoneal dose of 500 mg/kg in a rat. Liver and kidney damage have been reported in experimental animals. Tetrahydrofuran was found to be irritating to the skin of rabbits in aqueous solutions exceeding 20% concentration. Pulse pressure changes in animals have also been noted after exposures at concentrations of 200 ppm or greater.

Human

Tetrahydrofuran is a skin, eye, and mucous membrane irritant. It is also a narcotic in high concentrations. The lowest published toxic dose in humans is inhalation of 25,000 ppm. Several technicians performing experiments in which dogs were exposed at concentrations of tetrahydrofuran in air of 25,000 ppm and higher experienced severe headache, according to Lehmann et al (1943).

Occupational Exposure

NIOSH estimates that 75,000 workers have potential exposure to tetrahydrofuran each year.

Current Standards

Country	Maximum Allowable Concentrations
U.S.A., OSHA and ACGIH(TLV)	200 ppm; 590 mg/cu m
Germany	200 ppm; 590 mg/cu m
Finland	200 ppm; 590 mp/cu m
Rumania	200 mg/cu m (skin)
U.S.S.R.	100 mg/cu m
Yugoslavia	200 ppm; 590 mg/cu m

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