Michigan Department of Labor and Economic Opportunity
Michigan Occupational Safety and Health Administration
Consultation Education and Training Division

THE ISOCYANATES

INTRODUCTION

The isocyanates comprise a chemical family containing the reactive group, N=C=O. Probably the best known isocyanate is methyl isocyanate (MIC) which received worldwide attention when an industrial accident in Bhopal, India, in December 1984, released 40 tons of the gas to the surrounding community. More than 2,000 people died and over 100,000 were affected.

USAGE

The isocyanates are commonly used in industry. Diisocyanates are used in the production of polyurethane foams and elastomers, in phenol-formaldehyde resins to improve water and alkali resistance, in some paints such as automotive enamels and for bonding rubber to rayon or nylon. Monoisocyanates are often used in the treatment of cellulose and the production of some pesticides.

PHYSICAL/CHEMICAL PROPERTIES

The structural difference among the isocyanate compounds determines their physical/chemical properties which can affect their toxicity. Some isocyanates such as methylene diphenylisocyanate are solids at room temperature while others such as toluene diisocyanate or methyl isocyanate are readily vaporized liquids, and thus, have a higher likelihood of being inhaled at toxic concentrations.

Isocyanates react violently with bases, secondary or primary amines, acids, and alcohols. They should not be stored near these chemicals. These isocyanates may also react with water to produce a water-insoluble urea and carbon dioxide. Isocyanates should, therefore, be stored in closed containers to prevent water from entering because the water-isocyanate reaction can generate enough pressure to rupture containers. Stored isocyanates should also be protected from heat and direct sunlight because breakdown of the product may occur in such conditions.

The unreacted form (monomer) of an isocyanate is typically more toxic and more explosive than its reacted form (polymer). Thus, the more incomplete its polymerization, the more dangerous is the resulting compound.

HEALTH EFFECTS

Routes of Entry

Worker exposure to isocyanates can occur via inhalation, ingestion or skin and eye contact. Inhalation of isocyanates is the major route of entry. Generally speaking, if a worker can detect the odor of an isocyanate, such as the sweet, fruity, pungent odor of TDI or HDI, an overexposure probably exists since the odor threshold is higher than the exposure standard for these isocyanates. Other isocyanates, such as MDI, may be odorless.

Direct contact with skin or eyes can lead to serious localized reactions. Absorption through the skin by isocyanates is minimal. Although ingestion of isocyanates can be serious, worker exposure from ingestion of contaminated food, chewing tobacco, cigarettes, etc., is not as likely as exposure from the other routes.

Acute Exposures

Eye, nose and throat irritation and headaches can occur from inhalation of low level concentrations of isocyanates. Nausea and vomiting may also occur. Highly concentrated short (acute) exposures can cause serious lung problems including coughing, choking sensations, difficult and labored breathing (dyspnea), phlegm with possible fluid in the lungs (pulmonary edema), bronchitis and asthma. For some isocyanates such as TDI, respiratory symptoms may be delayed for 4 to 8 hours after exposure and can persist for 3 to 7 days. MDI may cause methemoglobinemia (an inability of the blood to carry oxygen). Liver, kidney, nerve problems, gastrointestinal effects and death, are possible but unlikely effects.

Isocyanates can cause severe irritation, second degree burns and dermatitis after a single skin contact. Severe irritation and inflammation (conjunctivitis) with possible discharge, also occurs if isocyanates contact the eyes.

Chronic Exposures

The isocyanates are well known for their ability to cause sensitization after exposures over days, months, or even years in a small percentage of the population. This sensitization, referred to by many scientists as allergy, is a reaction in which the individual becomes ill upon subsequent exposures to isocyanate concentrations much lower than those which cause illness in the general population. Respiratory symptoms, referred to by many scientists as asthma, are similar to those described above. Likewise, sensitization may occur after repeated skin contact resulting in "allergic dermatitis."

Although not considered sensitization, inflammation (conjunctivitis) with possible discharge may occur in eyes after repeated exposures to low concentrations for some isocyanates.

At this time, research data do not definitely demonstrate that isocyanates cause genetic mutation or reproductive or teratogenic effects (deformities) except in the case of MIC. An epidemiological study on pregnant women in Bhopal, India, reports significant increases in stillbirths after the MIC exposure. Inhalation studies (acute and chronic) on pregnant mice conclude significant increases in reproductive effects (infertility, fetal deaths, neonatal survival, resorptions) and significant internal and skeletal abnormalities.

Among the isocyanates, TDI is the best studied for the ability to cause cancer. In 1982, the National Toxicology Program (NTP) of the U. S. Department of Health and Human Services published laboratory studies in which rats and mice were administered commercial grade toluene diisocyanate (80% of 2,4-TDI and 20% of 2,6-TDI) through the oral route. TDI was carcinogenic to rats and female mice affecting connective tissue, the pancreas, liver and mammary glands. In another study published by an independent laboratory in 1983, commercial grade toluene diisocyanate (80% of 2,4-TDI and 20% of 2,6-TDI) was administered to mice and rats through the inhalation route and no cancer was observed. The International Agency for Research on Cancer (IARC) of the World Health Organization has rated TDI as having "sufficient evidence" for carcinogenicity in experimental animals due to the oral study. Since there are no data indicating cancer in humans from TDI exposure, IARC has indicated that there is "inadequate evidence" for carcinogenicity in humans.

The American Conference of Governmental Industrial Hygienists (ACGIH), TLV Committee, refers to the NTP bioassay, published criticisms of the study from an independent source and notes data from yet a third independent laboratory indicating no carcinogenicity in rats and mice in an inhalation experiment. They do not denote TDI as a carcinogen in the workplace.

MEDICAL SURVEILLANCE

Preplacement, annual and exit general physical examinations with special emphasis on the respiratory tract, spirometry and an extensive work history including pre-existing respiratory conditions such as asthma and smoking history are recommended. Workers with a history of respiratory conditions should be informed of the potential of increased health risk. Isocyanate-sensitized individuals should be assigned to work in areas where no exposure to isocyanates is expected.

EXPOSURE LIMITS

Table 1 shows the exposure limits listed by the Michigan Department of Public Health, Division of Occupational Health - MIOSHA, the National Institute of Occupational Safety and Health (NIOSH--the research branch of OSHA) and the American Conference of Governmental Industrial Hygienists (ACGIH) for some common isocyanates. MIOSHA's time-weighted averages (TWAs) were adopted in 1990. NIOSH and ACGIH exposure limits have also been identified.

TABLE 1
EXPOSURE LIMITS
(ppm = parts of isocyanate per million parts air)

	MIOSHA TWA[a]	NIOSH TWA[b]	ACGIH TLV/TWA[a]
Toluene Diisocyanate (TDI)	0.005 (STEL[e]=0.02) (STEL[e]=0.02)	[h] (IDLH[c] = 2.5)	0.005
Methylene Bisphenyl Isocyanate (MDI)	0.02[d]	0.005 (Ceiling[d] = 0.02) (IDLH[c] = 7.5)	0.005
1,6- Hexamethylene Diisocyanate (HDI)		0.005 (Ceiling[d] = 0.02)	0.005
Methyl Isocyanate (MIC)	0.02[g]	0.02[g] (IDLH[c] = 3)	0.02[g]
Isophorone Diisocyanate (IPDI)	0.005 (STEL[e]=0.02)	0.005[g] (STEL[f]=0.02)	0.005
Methylene bis(4-cyclohexyl isocyanate) (MCHI)	0.01[d]	(Ceiling[d] = 0.01)	0.005

[a] For inhalation exposures lasting 8 hours/day, 5 days/week. TLV - Threshold Limit value, TWA - Time Weighted Average.

[b] For inhalation exposures for up to a 10-hour workday during a 40-hour workweek.

[c] Immediately Dangerous to Life and Health (i.e., maximum escape level for 30 minutes)

[d] Ceiling concentration not to be exceeded for any 15-minute period time-weighted average in an 8-hour day.

[e] Short Term Exposure Limit (STEL) defined as a 15-minute, time-weighted average exposure not to be exceeded in an 8-hour day or for more than 4 times/day with 60 minutes between exposures.

[f] Short Term Exposure Limit (STEL) defined as a 15-minute, time-weighted average exposure not to be exceeded in an 8-hour day.

[g] Precautions against skin absorption necessary.

[h] Lowest feasible concentration.

EXPOSURE CONTROL MEASURES

Exposures to isocyanates can be controlled effectively through the use of engineering controls, personal protective equipment, work practice controls and through implementation of appropriate procedures during spill clean up.

Engineering Controls

The use of a completely enclosed ventilated process is one of the more common and effective control measures in reducing isocyanate exposure. Local exhaust ventilation, process modification, and isolation techniques are also commonly used.

Personal Protective Equipment (PPE)

When feasible engineering controls are incapable of reducing exposures below the TWA, PPE must be worn. Effective PPE for the isocyanates include supplied air respirators, impervious clothing and gloves and eye protection (preferably chemically resistant goggles).

Work Practice Controls

Proper chemical handling techniques designed to minimize exposure as well as safe operating procedures should be implemented. Personal hygiene practices including proper disposal of grossly contaminated clothing, washing slightly contaminated clothing, and washing skin with soap and water must be followed.

Spill Clean Up Procedures

Written emergency response plans for the clean up of isocyanate spills must be developed (see the Hazardous Waste Operations and Emergency Response Rules, Part 432, R 325.52101-R 325.52137). Only properly equipped and trained HazMat or emergency response teams are authorized for emergency spill response. All employees need to be trained in the potential health effects of a spill. Unprotected and unauthorized employees must be evacuated from the spill. Exposed or potentially exposed employees should wash immediately and thoroughly. If employees are exposed over the permissible exposure level or experience signs or symptoms from the spill, they must receive physical examinations. After an emergency response, such as an extinguished fire, the area should be inspected and decontaminated before unprotected workers are permitted to return. Notifications and reports to proper authorities may be required by RCRA or SARA Title III regulations.

Note: This guide is intended for the benefit of the public and may not contain all of the information pertinent to a specific hazard identification and/or control of personnel exposure. For further information, consult: MIOSHA, Consultation Education and Training Division, 530 W. Allegan Street, P.O. Box 30643, Lansing, Michigan 48909-8143. Telephone: (517) 284-7720.