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Toxicology Evaluation and Hazard Review for Non-CFC Containing Rigid Foams BKC 44317 and Last-A-Foam MSL-02A

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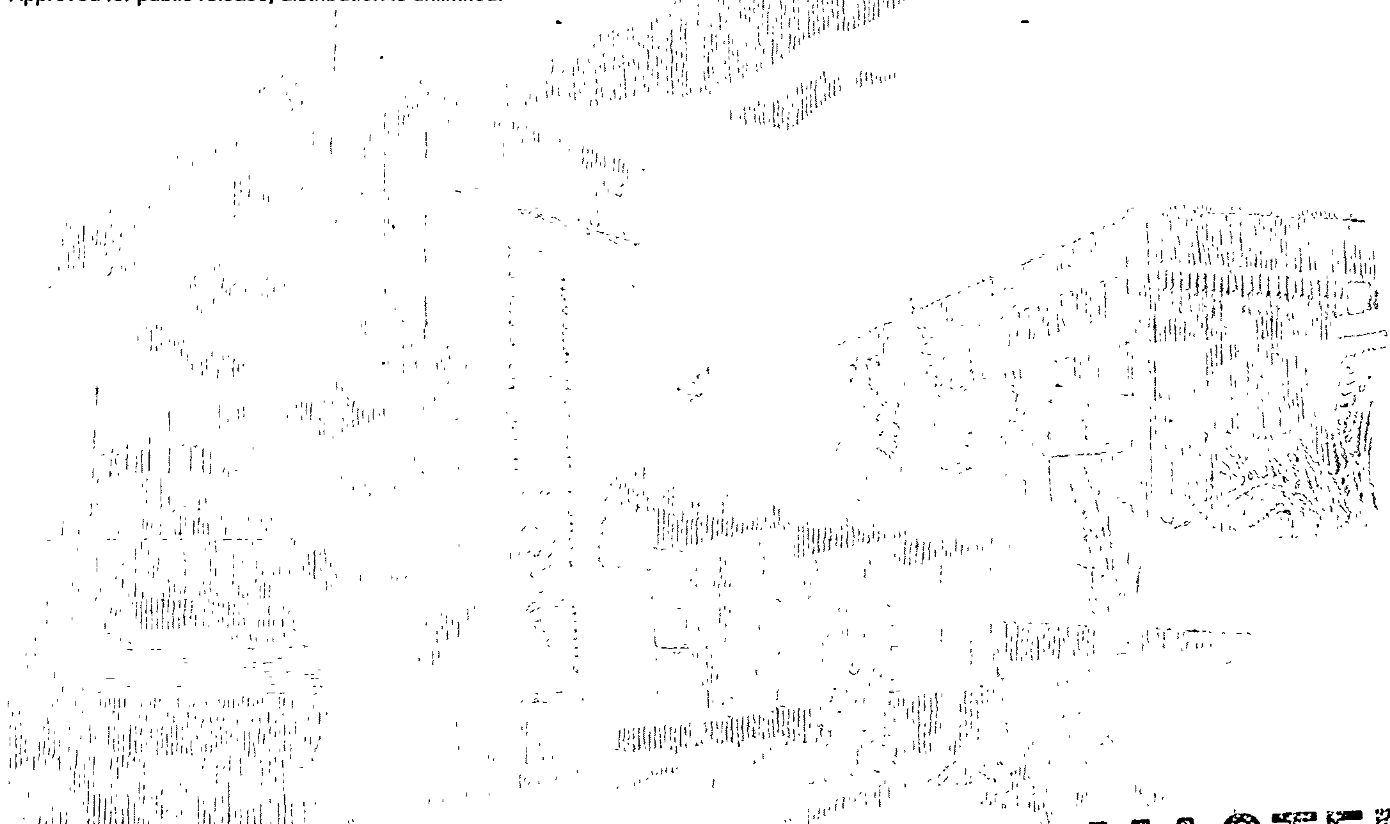

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Abstract

New pour-in-place, low density, rigid polyurethane foam kits have been developed to mechanically stabilize damaged explosive ordnance. Although earlier foam systems used chlorofluorocarbons as blowing agents, the current versions rely on carbon dioxide generated by the reaction of isocynates with water. In addition, these kits were developed to manually generate small quantities of rigid foam in the field with minimal or no protective equipment. The purpose of this study was to evaluate and summarize available hazard information for the components of these rigid foam kits and to provide recommendations for personal protective equipment to be used while performing the manual combination of the components. As with most rigid foam systems, these kits consist of two parts, one a mixture of isocyanates; the other, a combination of polyols, surfactants, and amine catalysts. Once completely deployed, the rigid foam is non-toxic. The components, however, have some important health effects which must be considered when establishing handling procedures.

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Nomenclature

ACGIH	American Conference of Governmental Industrial Hygienists
CAS	Chemical Abstract Service
Ceiling	Airborne concentration of a substance that should not be exceeded during any part of a working exposure.
COC	Cleveland open cup. A method for determining the flash point of a liquid.
Draize test	Test for skin or eye irritation in which rabbit skin or rabbit eyes are exposed to the material in question for 24 hours. Degree of irritation is based on symptoms evidenced at 24 and 72 hours after exposure.
g	Gram
IARC	International Agency for Research on Cancer
kg	Kilogram
LC50	Lethal concentration 50%. The concentration of a substance administered by inhalation that can be expected to cause death in 50 percent of the exposed animals.
LD50	Lethal dose 50%. The dose of a substance that can be expected to cause death in 50 percent of the exposed animals.
m^3	Cubic meters
MDA	Methylene dianiline
MDI	Methylene diisocyanate or methylene bisphenyl isocyanate
µg	Microgram
mg	Milligram
ml	Milliliter
mm	Millimeter

Nomenclature

MSHA	Mining Safety and Health Administration
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OC	Open cup. A method for determining the flash point of a liquid.
OSHA	Occupational Safety and Health Administration
PAPI®	Trademark for a series of methylene diphenyl diisocyanate urethane polymers.
PEL	OSHA Permissible exposure limit. It is the airborne concentration of a substance generally considered safe for repeated exposure of most workers without adverse health effects.
PMCC	Pensky-Martens closed cup. A method for determining the flash point of a liquid.
PMPPI	Polymethylene polyphenyl isocyanate
PPM	Parts per million
PVC	Polyvinyl chloride
REL	NIOSH Recommended exposure limit, published in a NIOSH criteria document for the substance or a class of related materials. It is the airborne concentration of a substance generally considered safe for repeated exposure of most workers without adverse health effects.
SCBA	Self-contained breathing apparatus
TCC	Tag closed cup. A method for determining the flash point of a liquid.
TLV	ACGIH Threshold limit value. It is the airborne concentration of a substance generally considered safe for repeated exposure of most workers without adverse health effects.

Nomenclature

TWA — Time-weighted average. It is the airborne concentration of a substance generally considered safe for repeated exposure of most workers during a normal 8-hour workday/40-hour workweek without adverse health effects.

Toxicology Evaluation And Hazard Review For Non-CFC Containing Rigid Foams BKC 44317 And Last-A-Foam® MSL-02A

Introduction

Low-density, rigid polyurethane foam is being used to mechanically stabilize damaged explosive ordnance. Small quantities (less than 1 cup) of two components are combined, shaken together, and poured into the ordnance. Previous studies have indicated that the final foam product is essentially non-toxic [1]. The unreacted starting materials, however, have potential health effects which should be considered when establishing handling procedures.

Two rigid foams are currently be evaluated for use in ordnance disposal, BKC 44317 produced by Allied Signal Kansas City Division and Last-A-Foam® MSL-02A produced by General Plastics Manufacturing Company of Tacoma, WA. BKC 44317 consists of an R-component and a T-component [2]. The R-component is a mixture of polyols, surfactants, and amine catalysts, specifically polypropylene triol (0–69%), propoxylated sucrose (0–69%), Poly-G® 85-28 (23%), DABCO® DC197 surfactant (3%), oxybispropanol (< 1%), and triethylenediamine catalyst (< 1%). The T-component is PAPI® formulation 2580, consisting of 65–75% polymethylene polyphenyl isocyanate and 25–35% methylene bisphenyl isocyanate (predominantly 4,4'-diphenylmethane diisocyanate with small amounts of the o,p-isomer) [3]. Approximately 100 grams of the R-component are mixed with 160 grams of the T-component to generate the final rigid foam product.

The information provided by the manufacturer's MSDS for Last-A-Foam® MSL-02A [4] indicates that it is also a two-part foam, one part a 50/50 mixture of MDI and MDI polymers; the other, a proprietary polyether polyol mixture expected to be similar to the formulation used in the BKC 44317 rigid foam. Approximately 150 grams of the isocyanates (Part A) are combined with 180 grams of the polyol mixture (Part B) to form the final rigid foam.

The rigid foams used prior to the 1987 Montreal Protocol relied upon chlorofluorocarbon (CFC) compounds as blowing agents to deploy the foam. The hazards of rigid foams containing CFC's were reviewed by Archuleta and Stocum in 1994 [1]. The new pour-in-place kits, designed to generate small quantities of rigid foam in the field, use carbon dioxide, generated by the reaction of isocyanates with water, as the foaming agent. General hazard information, personal protection recommendations, and flammability data for these two rigid foam kits are similar and were summarized in a memorandum to Roger Hartman in June 1995 [5]. This report describes the current chemical and toxicological literature on the individual constituents of the BKC 44317 formulation. The descriptive toxicity classes (e.g., relatively harmless, slightly toxic, etc.) are based on those in *Proctor and Hughes' Chemical Hazards in the Workplace* [6]. Finally, the report also discusses flammability and reactivity data and provides recommendations for personal protective equipment to be used when handling the foam components.

Polypropylene Triol

Chemical Name [7]:
Polypropylene triol

Molecular Formula [8]:
$CH_2(OC_3H_6)_xOH–CH(OC_3H_6)_xOH–CH_2(OC_3H_6)_xOH$ where $x \approx 23$

CAS Number:
25791-96-2

Chemical and Physical Properties [7]:
Appearance: Clear, viscous liquid
Odor: Mild. No threshold data are available.
Vapor Pressure: < 0.3 mm at 68° F (20° C)
Specific Gravity: 1.01–1.03
Melting Point: < –13° F (< –25° C)
Boiling Point: Decomposes
Flash Point: 300–500° F (148–260° C), PMCC

Exposure Limits: Occupational exposure limits have not been established for this material by ACGIH, OSHA, or NIOSH [7, 9].

Toxicology: Polypropylene triol is found to be mildly irritating to eyes and skin and slightly hazardous by ingestion. No information is available on adverse effects following skin absorption or inhalation exposure. The following accute toxicity data are available for Voranol 2070 and NIAX L-56 polyols, which are essentially 100% polypropylene triol:

Dermal - rabbit LD50: > 16–20 g/kg [10]
Dermal, Open Draize Test - rabbit: A 500 mg dose was mildly irritating [10].
Orat - rat LD50: 2.0–2.9 g/kg for NIAX LG-168 [11, 12]
Oral - rat LD50: > 65 g/kg for NIAX L-56 [8, 10, 13]

Acute Exposure: Polypropylene triol is slightly toxic by ingestion. Skin or eye contact may cause irritation [7].

Chronic Exposure: Information on the effects of chronic exposure to polypropylene triol is not available [7].

Inhalation Exposure: Information on the effects of inhalation of polypropylene triol is not available [7]. Under the anticipated conditions of use, i.e., small quantities in a field environment, its low vapor pressure should preclude any inhalation hazard at normal temperatures.

Dermal Exposure: Dermal contact, expected to be the primary route of exposure, may cause acute irritation with redness of the skin [7]. Evaluation of propylene triols for dermal effects using the Open Draize test indicates that exposures of 0.5 g result in mild irritation. A dermal LD50 of > 16–20 g/kg has been established in rabbits [8, 10].

Oral Exposure: Ingestion of polypropylene triol may cause acute nausea, vomiting, diarrhea, and abdominal discomfort [7].

Eye Exposure: Eye contact with polypropylene triol as a liquid or mist may cause acute irritation with redness of the conjuctiva and possible slight transient corneal injury [7, 12].

Carcinogenicity: Polypropylene triol is not listed as a carcinogen by NTP, IARC, ACGIH, or OSHA [7, 9]. Furthermore, similar polyols do not cause cancer in animals [11, 12].

Reproductive Effects: There are no known reproductive effects following exposure to propylene triol, and studies have shown that exposure to other propylene glycols does not result in adverse reproductive effects [7].

Flammability: Propylene triol is considered a slight fire hazard only when exposed to extreme heat or flames. It is classified as an OSHA Class IIIB combustible liquid (flash point at or above 200° F) with NFPA ratings of 1 for flammability (materials which must be preheated before ignition can occur) and 0 for reactivity (materials which are normally stable, even during exposure to fire or water) [7].

Incompatibility: Reaction of polypropylene triol with strong oxidizers can create a fire or explosion hazard [7].

Hazardous Decomposition Products: Thermal decomposition produces carbon monoxide and carbon dioxide [7].

Personal Protective Equipment: When using pure polypropylene triol, chemical safety goggles, compatible chemical-resistant gloves, and appropriate protective clothing to prevent repeated or prolonged skin or eye contact are recommended.

Under conditions that may generate an airborne exposure, the need for respiratory protection should be determined by air monitoring. When respiratory protection is necessary, a NIOSH/MSHA-approved respirator is recommended. Selection of the appropriate equipment must be based on the specific operation and on the contamination levels encountered at the site. For protection from airborne exposure, the least restrictive respirator recommended for use with polypropylene triol is a chemical cartridge respirator with an organic vapor cartridge and full facepiece [7].

Propoxylated Sucrose

Chemical Name [14]:
Propoxylated sucrose
Polypropylene glycol sucrose ether

Molecular Formula [14]:
Polymer, structure not available

CAS Number:
9049-71-2

Chemical and Physical Properties [14]:
Appearance: Solid
Odor: No data available
Vapor Pressure: No data available
Melting Point: No data available
Boiling Point: Not applicable
Flash Point: No data available

Exposure Limits: Occupational exposure limits have not been established for this material by ACGIH, OSHA, or NIOSH [9, 14].

Toxicology: Although toxicological information is not available for polypropylene glycol sucrose ethers, comparable data for polypropylene glycol butyl ethers are presented below. Data for both propylene and polypropylene glycol ethers indicate that oral and inhalation hazards decrease with increasing molecular weight [15].

Acute Exposure: Information on the effects of acute exposure to polypropylene glycol sucrose ether is not available [14]. However, by comparison to polypropylene glycol butyl ethers, it is not expected to pose a significant hazard following inhalation, dermal or oral exposure.

Chronic Exposure: Information on the effects of chronic exposure to polypropylene glycol sucrose ether is not available [14].

Inhalation Exposure: Polymer-based glycol ethers are not expected to pose a significant inhalation hazard due to their low vapor pressure at normal temperatures (< 0.1 mm Hg for the butyl ether). Rats exposed to saturated atmospheres of polypropylene glycol butyl ethers for 8 hours suffered no ill effects and developed only mild effects when exposed to fogs of the same materials for 8 hours [15].

Dermal Exposure: Polypropylene glycol butyl ethers were only slightly irritating in rabbit dermal studies. Futhermore, human dermal studies showed that higher molecular weight polymers were neither skin irritants nor sensitizers. The butyl ethers are not readily absorbed through the skin in acutely toxic amounts. However, repeated applications of the lower molecular weight compound in oil to rabbit skin for 30 days resulted in moderate toxicity, while the higher molecular weight polymer exhibited low toxicity under the same conditions [15].

Oral Exposure: Oral LD50 values for exposure of male rats to polypropylene glycol butyl ethers range from 5.8 to 9.2 g/kg (practically non-toxic), depending on the molecular weight of the polymer. The higher molecular weight polymers appear to be less readily absorbed from the digestive tract than those with lower molecular weights [15].

Eye Exposure: In studies using rabbits, polypropylene glycol butyl ethers were no more than very slightly irritating to the eyes [15].

Carcinogenicity: Polypropylene glycol ethers are not listed as carcinogens by NTP, IARC, ACGIH, or OSHA [9, 14].

Reproductive Effects: There are no known reproductive effects associated with polypropylene glycol butyl or sucrose ethers [14, 15].

Flammability: Polypropylene glycol sucrose ether is considered a slight fire hazard only when exposed to extreme heat or flames. The NFPA ratings are 1 for flammability (materials which must be preheated before ignition can occur) and 0 for reactivity (materials which are normally stable, even during exposure to fire or water) [14].

Incompatibility: Reaction of polypropylene glycol sucrose ether with strong oxidizers can create a fire or explosion hazard [14].

Hazardous Decomposition Products: Thermal decomposition produces carbon monoxide and carbon dioxide [14].

Personal Protective Equipment: When using pure polypropylene glycol sucrose ether, splash-proof or other appropriate safety goggles, compatible chemical-resistant gloves, and appropriate protective clothing to prevent repeated or prolonged skin or eye contact are recommended.

Under conditions that may generate an airborne exposure, the need for respiratory protection should be determined by air monitoring. When respiratory protection is necessary, a NIOSH/MSHA-approved respirator is recommended. Selection of the appropriate equipment must be based on the the specific operation and on the contamination levels encountered at the site. For protection from airborne exposure, the least restrictive respirator recommended for use with polypropylene glycol sucrose ether is any dust and mist respirator [14].

Poly-G® 85-28

Chemical Name [16]:

Polyether triol
Chemical family: Hydroxy-terminated poly(oxyalkylene) polyol
Poly-G® is a trademark for a series of polyethylene and polypropylene glycols and polyoxypropylene adducts of glycerol [17]

Molecular Formula [16]:

Mixture, 99–100% polyether triol

CAS Number [16]:

9082-00-2

Chemical and Physical Properties [16]:

Appearance: Clear, colorless to slightly yellow liquid
Odor: Slightly musty to odorless
Vapor Pressure: 0.01–3.5 mm Hg at 77° F (25° C)
Specific Gravity: 0.9–1.1
Melting Point: Not available
Boiling Point: Not available
Flash Point: 300–500° F (150–260° C), COC

Exposure Limits: Occupational exposure limits have not been established for this material by ACGIH, OSHA, or NIOSH [9, 16, 18].

Toxicology [16]:

Inhalation - rat LC50: > 2×10^5 mg/m^3 for 1 hour
Dermal - rabbit LD50: > 2 g/kg
Oral - rat LD50: > 5 g/kg [16]; > 19 g/kg [18]

Acute Exposure: Poly-G® 85-28 exhibits no significant adverse effects following inhalation, dermal, or eye exposure. However, the manufacturer suggests that ingestion may cause symptoms of gastrointestinal discomfort including nausea, vomiting, and diarrhea [16].

Chronic Exposure: The only reported effects of chronic exposure to Poly-G® 85-28 are similar to those resulting from a single exposure [16].

Inhalation Exposure: The inhalation LC50 of > 2 x 10^5 mg/m^3 (1-hour exposure) for Poly-G® 85-28 suggests that the material is practically non-toxic when inhaled.

Dermal Exposure: The dermal LD50 of > 2 g/kg for Poly-G® 85-28 classifies the material as practically non-toxic following dermal exposure. The manufacturers of similar polyether triol products indicate that these materials are not primary skin irritants [16, 19, 20].

Oral Exposure: Ingestion of Poly-G® 85-28 may cause symptoms of gastrointestinal discomfort including nausea, vomiting, diarrhea, or lethargy [16]. However, the oral LD50 of > 5 g/kg would rate the material as practically non-toxic when ingested.

Eye Exposure: The manufacturer of Poly-G® 85-28, Olin Corporation, reports no significant effects from eye exposure[16]. The manufacturer of a similar product, however, mentions the possibility of conjunctival irritation and redness on exposure to the product in the form of a liquid or mist [20].

Carcinogenicity: Poly-G® 85-28 and polyether triols in general are not listed as carcinogens by NTP, IARC, ACGIH, or OSHA [9, 16].

Reproductive Effects: There are no known reproductive or mutagenic effects following exposure to Poly-G® 85-28 [16].

Flammability: The manufacturer Poly-G® 85-28 states that it is neither flammable or combustible and has no NFPA ratings [16]. However, similar products (essentially 100% polyether triols) from other manufacturers are designated fire hazards when exposed to heat or flames. These compounds are generally classified as OSHA Class IIIB combustible liquids (flash point at or above 200° F) [19, 20] with NFPA ratings of 1 for flammability (materials which must be preheated before ignition can occur) and 0 for reactivity (materials which are normally stable, even during exposure to fire or water) [18, 19, 20].

Incompatibility: Reaction of Poly-G® 85-28 with strong oxidizers can create a fire or explosion hazard [16, 18].

Hazardous Decomposition Products: Thermal decomposition produces carbon monoxide, carbon dioxide, and other unidentified molecular fragments [16].

Personal Protective Equipment: According to the manufacturer, gloves, protective clothing, and respirators are not normally required when working with Poly-G® 85-28. Safety glasses with side shields or safety goggles, however, are recommended, to prevent eye exposure [16].

Under conditions that may generate an airborne exposure, the need for respiratory protection should be determined by air monitoring. When respiratory protection is necessary, a NIOSH/MSHA-approved respirator is recommended. Selection of the appropriate equipment must be based on the the specific operation and on the contamination levels encountered at the site. For protection from airborne exposure, the least restrictive respirator recommended for use with polyether triols is a chemical cartridge respirator with an organic vapor cartridge [19].

DABCO® DC197 Surfactant

Chemical Name [21, 22]:
DABCO® DC197 Surfactant
Dimethylpolysiloxane (polyoxyethyleneglycol) silicone copolymer [1]
Family: Silicone
Silicone oil polymer

Molecular Formula [21]:
Proprietary mixture

CAS Number [1]:
68037-63-8
68937-54-2

Chemical and Physical Properties [21]:
Appearance: White or colorless mobile liquid
Odor: Faint odor
Vapor Pressure: Not available
Specific Gravity: 1
Melting Point: Not applicable
Boiling Point: 250° F (121° C)
Flash Point: 160° F (71° C), TCC

Exposure Limits: Occupational exposure limits have not been established for DABCO® DC197 Surfactant by ACGIH, OSHA, or NIOSH [9, 21].

Toxicology: There is little toxicological information available for DABCO® DC197 Surfactant. Major routes of exposure are ingestion and inhalation. The compound is also a moderate eye irritant [21].

Acute Exposure: Exposure to DABCO® DC197 Surfactant may cause transient eye irritation. Ingestion may cause headache or gastrointestinal symptoms [21].

Chronic Exposure: The manufacturer reports that there is no information available on the adverse effects of chronic exposure to DABCO® DC197 Surfactant [21]. However, repeated or prolonged exposure of the skin to silicone oil polymers may cause primary skin irritation and dermatitis [1].

Inhalation Exposure: No information is available on the adverse effects of DABCO® DC197 Surfactant following inhalation exposure [21].

Dermal Exposure: The manufacturer reports that there is no information available on the adverse effects of dermal exposure to DABCO® DC197 Surfactant [21]. However, repeated or prolonged exposures (24 to 48 hours) may irritate the skin, leading to dermatitis [1].

Oral Exposure: Silicones generally have very low oral toxicity [1]. The manufacturer reports that ingestion of DABCO® DC197 Surfactant may cause headache or mild gastrointestinal symptoms, such as nausea and vomiting [21].

Eye Exposure: Eye contact with DABCO® DC197 Surfactant may cause temporary irritation, redness, or discomfort [21].

Carcinogenicity: DABCO® DC197 Surfactant is not listed as a carcinogen by NTP, IARC, ACGIH, or OSHA [9, 21]. In addition, a 1984 genetic study using Salmonella typhimurium and Escherichia coli reverse mutation assays showed no evidence of genetic activity [21].

Reproductive Effects: The manufacturer reports that there are no known reproductive effects following exposure to DABCO® DC197 Surfactant [21].

Flammability: DABCO® DC197 Surfactant is considered a moderate fire hazard when exposed to heat or flames and, when ignited, will give rise to a Class B fire (one involving flammable liquids or gases). It is classified as an OSHA Class IIIA combustible liquid (flash point between 140° F and 200° F) with NFPA ratings of 2 for health (materials for which intense or continued exposure may cause temporary incapacitation or requires prompt medical treatment to avoid residual injury), 2 for flammability (materials which must be moderately heated or exposed to relatively high temperatures before ignition can occur), and 0 for reactivity (materials which are normally stable, even during exposure to fire or water) [21].

Incompatibility: Interaction of DABCO® DC197 with strong oxidizers, such as perchlorates or nitrates, may create a fire or explosion hazard [21].

Hazardous Decomposition Products: Thermal decomposition produces carbon monoxide, carbon dioxide, and silicon dioxide [21].

Personal Protective Equipment: When using pure DABCO® DC197 Surfactant, chemical splash goggles and long-sleeved protective clothing are recommended. Hand protection is not required under normal conditions, unless repeated or prolonged exposure is expected.

Under conditions that may generate an airborne exposure, the need for respiratory protection should be determined by air monitoring. When respiratory protection is necessary, a NIOSH/MSHA-approved respirator is recommended. Selection of the appropriate equipment must be based on the the specific operation and on the contamination levels encountered at the site. For protection from airborne exposure, the least restrictive respirator recommended for use with DABCO® DC197 is a chemical cartridge respirator with half- or full-face shield and an organic vapor cartridge [21, 23].

Triethylenediamine

Chemical Name [24]:
Triethylenediamine
TEDA
Bicyclo(2,2,2)-1,4-diazoctane

Molecular Formula [24]:
$N{-}(CH_2CH_2)_3{-}N$

CAS Number:
280-57-9

Chemical and Physical Properties [24]:
Appearance: White hygroscopic crystals
Odor: Sharp, ammonia-like
Vapor Pressure: 0.45 mm Hg at 68° F (20° C) [24]. Sublimes readily at room temperature [25].
Specific Gravity: 1.14
Melting Point: 316° F (158° C)
Boiling Point: 345° F (174° C)
Flash Point: > 122° F (> 50° C)

Exposure Limits: Occupational exposure limits have not been established for triethylenediamine by ACGIH, OSHA, or NIOSH [9, 24].

Toxicology: Triethylenediamine (TEDA), a strong base, is corrosive if inhaled, ingested, or splashed on the skin or eyes. Repeated exposure may cause sensitization [24].

Dermal - rabbit LD50: > 3.2 g/kg for a 25% aqueous solution [25, 26]
Dermal - rabbit LD50: > 2 g/kg [25, 26]
Dermal, Open Draize Test - rabbit: 2.5 mg dose was mildly irritating [13, 27]
Oral - rat LD50: 0.7–1.8 g/kg [25, 26]
Oral - mouse LD50: 0.2 g/kg [25, 26]
Eye, Standard Draize Test - rabbit: 25 mg dose was moderately irritating [13, 27]

Acute Exposure: Triethylenediamine is considered moderately toxic by ingestion [24]. Ingestion causes muscle weakness, contraction, or spasticity and generally depressed activity in rabbits and guinea pigs [13]. Acute exposure may result in severe irritation and burning of the upper respiratory tract, eyes, or skin [27].

Chronic Exposure: Long-term exposure to triethylenediamine may produce inflammation and ulceration of the mouth, bronchial and gastrointestinal symptoms, dermatitis, or conjunctivitis, depending on the concentration and duration of exposure [24]. Although similar amines have caused respiratory and dermal sensitization, these symptoms have not been reported for this chemical [27].

Inhalation Exposure: Because triethylenediamine is hygroscopic and should be oxidized very rapidly in air, it is unlikely that significant amounts will be found in the air. Exposure to concentrated TEDA vapor (concentration not reported) caused mild irritation of the eyes, nose, and throat with changes in breathing pattern in mice and rats. The irritation disappeared when exposure was discontinued [25]. Exposure to alkaline corrosives has caused burns to mucous membranes, fluid buildup in the lungs, or death in severe cases. Repeated inhalation exposure may cause respiratory sensitization with wheezing, difficulty breathing, sneezing, and runny or blocked nose [24].

Dermal Exposure: Application of a 3.3% solution of a DABCO® product which is essentially 100% triethylenediamine to 50 human subjects, followed by 12 more exposures at lower concentrations, produced dermal irritation in 3 subjects after one or two applications. Four of six subjects in a closed patch test using a 25% solution experienced irritation [26]. When a similar solution was applied to rabbit skin, reddening, mild irritation, and some death of skin tissure was seen 24 hours after application [25, 26].

Oral Exposure: Based on the oral LD50 of 0.7–1.8 g/kg, triethylenediamine would be classified as slightly toxic. Although ingestion is not a likely route of exposure to TEDA in the work environment, acute oral exposure to alkaline corrosives may cause immediate pain, burns around the mouth and mucous membranes, gastrointestinal symptoms from esophageal or stomach injury, respiratory distress from epiglottal edema, circulatory collapse, and renal failure. Even years after severe exposures, narrowing of esophageal or gastric passages and death may be attributable to complications of the exposure [24].

Eye Exposure: Human exposure to triethylenediamine vapors induces swelling of the corneal epithelial cells, leading to reversible symptoms of blurred vision or the appearance of colored haloes around lights. Cats and monkeys exposed to TEDA exhibited similar cell damage, which healed after several days [28, 29]. Rabbits exposed to 0.5 ml of a TEDA solution in water experienced minor corneal irritation with a 5% solution, moderate injury with a 15% solution, and corneal burns with a 25% solution [26].

Carcinogenicity: Triethylenediamine produced no mutations in a short-term Ames test with Salmonella typhimurium TA-100 [25, 26], although one study is not considered adequate proof of non-mutagenicity. In addition, no positive mutagenic effects were detected in workers exposed to low doses of isocyanates and amines during the production of polyurethane foams [30].

Reproductive Effects: There are no known reproductive effects following exposure to triethylenediamine [24, 25].

Flammability: Triethylenediamine, a flammable or combustible solid, is considered a moderate fire hazard when exposed to heat or flames [24]. It readily sublimes at room temperature, producing vapors that may travel to the ignition source and flash back [31]. The NFPA ratings are 2 for health (materials for which intense or continued exposure may cause temporary incapacitation or requires prompt medical treatment to avoid residual injury), 2 for flammability (materials which must be moderately heated or exposed to relatively high temperatures before ignition can occur), and 0 for reactivity (materials which are normally stable, even during exposure to fire or water) [24].

Incompatibility: Triethylenediamine undergoes a very exothermic reaction with cellulose nitrate and may ignite upon mixing. It also forms an explosive complex with hydrogen peroxide. Violent reactions with strong acids and strong oxidizers may also create a fire and explosion hazard [24, 32].

Hazardous Decomposition Products: Thermal decomposition produces carbon monoxide, carbon dioxide, and nitrogen oxides [24].

Personal Protective Equipment: When using pure triethylenediamine, splash-proof or other appropriate safety goggles and possibly a face shield, compatible chemical-resistant gloves, and appropriate protective clothing to prevent repeated or prolonged skin or eye contact are recommended. The following glove materials are recommended for the chemical family of polyamines: Viton provides good protection; natural rubber, nitrile rubber, and PVC provide fair to poor protection; and butyl rubber and neoprene provide acceptable protection [25].

Under conditions that may generate an airborne exposure, the need for respiratory protection should be determined by air monitoring. When respiratory protection is necessary, a NIOSH/MSHA-approved respirator is recommended; and selection of the appropriate equipment must be based on the contamination levels encountered at the site and on the specific operation. For protection from airborne exposure, the least restrictive respirator recommended for use with TEDA is any dust or mist respirator [24, 25].

Oxybispropanol

Chemical Name [33]:

Oxybispropanol
Dipropylene glycol

Molecular Formula [33]: Three linear isomers of oxybispropanol are possible, but the exact composition of the commercial product is uncertain [34].

$(CH_3CH(OH)CH_2)_2O$

CAS Number:

25265-71-8

Chemical and Physical Properties [33]:

Appearance: Colorless, slightly viscous liquid
Odor: Odorless
Vapor Pressure: 0.03 mm Hg at 68° F (20° C)
Specific Gravity: 1.02–1.04
Melting Point: Not available
Boiling Point: 444–450° F (229–232° C)
Flash Point: 250° F (121° C), PMCC

Exposure Limits: Occupational exposure limits have not been established for oxybispropanol by ACGIH, OSHA, or NIOSH [9, 33].

Toxicology: It is unclear whether the oxybispropanol used in this rigid foam product or in the toxicological tests reported is one isomer or a mixture of isomers. Therefore information for all isomers of oxybispropanol was included in this review.

The most probable routes of human exposure in an industrial environment are dermal absorption and inhalation of mists from heated or violently agitated materials. Oral, eye, dermal, and inhalation toxicities are all considered to be low. Animal data have been used to estimate an acute oral lethal dose of > 1 pint for 100-pound adult humans, indicating that this material is only slightly toxic [31, 35].

Dermal - rabbit LD50: > 5 g/kg [33]; > 21 g/kg [10, 13]
Oral - rat LD50: 14.8–15.0 g/kg [33, 34]
Eye, Standard Draize Test - rabbit: A 500 mg dose was mildly irritating [13].

Acute Exposure: Oxybispropanol is only slightly toxic by dermal absorption and ingestion [33].

Chronic Exposure: Dermal exposure to oxybispropanol resulted in only minor skin irritation and negligible skin absorption, while oral exposure to a 5% solution in water produced minimal physiological damage [33].

Inhalation Exposure: Although few data are available on inhalation exposure, the low vapor pressure and low overall toxicity of oxybispropanol should preclude injury by this route unless large quantities are heated in a confined space. Inhalation of mists generated by heat or agitation may cause irritation, sore throat, coughing, or headache [33, 34].

Dermal Exposure: Repeated applications of oxybispropanol to rabbit skin (10 doses in 12 days) produced essentially no irritation [33, 34]. There is no indication that the chemical is absorbed throught intact skin [31, 34].

Oral Exposure: The oral rat LD50 of 14.8 g/kg classifies oxybispropanol as practically non-toxic. Rats and chicks were unaffected by oral exposure to a solution containing 5% oxybispropanol in drinking water for 77 or 27 days, respectively. Exposure of rats to a 10% solution, however, resulted in death due to kidney or liver damage [33, 34]. Single doses of 5.2 g/kg administered orally to dogs produced no evidence of toxicity and disappeared from the blood in approximately 24 hours, although central nervous system depression has been observed in dogs receiving 6.2 g/kg intravenous doses[31, 35].

Eye Exposure: The Standard Draize Test, using a 500 mg dose of oxybispropanol, produced no significant eye irritation or injury in rabbits [13].

Carcinogenicity: Oxybispropanol is not listed as a carcinogen by NTP, IARC, ACGIH, or OSHA [9, 33].

Reproductive Effects: Rats exposed to 0.8 g/kg/day of oxybispropanol exhibited no maternal or developmental toxicity. Doses of 2.0 and 5.0 g/kg/day (mid and high doses) caused some maternal deaths (4% and 9% of the test populations, respectively), but no developmental toxicity was observed even in the fatal cases [36]. Pregnant rabbits, given doses of 0, 0.2, 0.4, 0.8, or 1.2 g/kg/day for 14 days, experienced no maternal deaths or other clinical signs of toxicity; and their fetuses showed no unusual weight loss or malformations [37].

Flammability: Oxybispropanol is considered a slight fire hazard when exposed to heat or flames. It is classified as an OSHA Class IIIB combustible liquid (flash point at or above 200° F) with NFPA ratings of 1 for health (materials causing irritation but only minor residual injury even with no treatment), 1 for flammability (materials which must be preheated before ignition can occur), and 0 for reactivity (materials which are normally stable, even during exposure to fire or water) [33].

Incompatibility: Reaction of oxybispropanol with strong acids and oxidizers can create a fire or explosion hazard [33].

Hazardous Decomposition Products: Thermal decomposition may produce carbon monoxide, carbon dioxide, and unidentified organic acids and aldehydes [33].

Personal Protective Equipment: When using pure oxybispropanol, splash-proof or other appropriate safety goggles, compatible chemical-resistant gloves, and appropriate protective clothing to prevent repeated or prolonged skin or eye contact are recommended.

Under conditions that may generate an airborne exposure, the need for respiratory protection should be determined by air monitoring. When respiratory protection is necessary, a NIOSH/MSHA-approved respirator is recommended. Selection of the appropriate equipment must be based on the the specific operation and on the contamination levels encountered at the site. For protection from airborne exposure, the least restrictive respirator recommended for use with oxybispropanol is a chemical cartridge respirator with an organic vapor cartridge [33].

PAPI® 2580

The T-component of the BKC 44317 rigid foam is Dow Corning PAPI® 2580 polymeric MDI, listed in the MSDS as a mixture of polymethylene polyphenyl isocyanate (PMPPI, CAS 9016-87-9), diphenylmethane diisocyanate (CAS 26447-40-5), and methylene bisphenyl isocyanate (MDI, CAS 101-68-8). The properties and hazards listed in this section are for isocyanates in general and for the PAPI® materials. For properties and hazards specific to methylene bisphenyl isocyanate, which has been studied in greater detail than the other components, see the next section.

Chemical Name [2, 38, 39]:
PAPI® 2580 polymeric MDI
ASANB621
BKC 44317 T-component

Molecular Formula:
For Polymeric MDI [40]: $OCN–C_6H_4–(CH_2C_6H_3–NCO)_x–CH_2–C_6H_4–NCO$
For PAPI® 2580 [39]:
65–75% PMPPI
25–35% Diphenylmethane diisocyanate/methylene bisphenyl isocyanate

CAS Numbers [39]:
9016-87-9 (PMPPI)
26447-40-5 (Diphenylmethane diisocyanate)
101-68-8 (MDI)

Chemical and Physical Properties [38, 39]:
Appearance: Dark amber to brown, viscous liquid
Odor: Pungent earthy or musty odor. The odor threshold of 0.1 PPM [41] or 0.4 PPM [38] exceeds the TLV for MDI (0.005 PPM) [9].
Vapor Pressure: < 1 x 10^{-5} at 77° F (25° C)
Specific Gravity: 1.23
Melting Point: < 50° F (< 10° C)
Boiling Point: 392–406° F (200–208° C) for PMPPI or 525° F (274° C) with decomposition for PAPI® 2580
Flash Point: 350–425° F (177–218° C), CC for PMPPI or > 410° F (> 21° C), COC for PAPI® 2580

Exposure Limits: Occupational exposure limits have not been established for PAPI® 2580 by ACGIH, OSHA, or NIOSH [9, 38]. See the following section for established exposure limits for MDI.

Toxicology: The majority of data in the literature refer to the toxicology of polymethylene polyphenyl isocyanates (PMPPI) and methylene bisphenyl isocyanate (MDI) in general, rather than to PAPI® 2580 specifically. This section contains information related to either PMPPI or PAPI® 2580, as indicated in the text. For the toxicological hazards of MDI, see the next section.

PAPI® [39]
Dermal - rabbit LD50: > 9.4 g/kg
Oral - rat LD50: > 10 g/kg

PMPPI [40]
Inhalation - rat LC50: 490 mg/m³ for a 4-hour aerosol exposure
Dermal - rabbit LD50: > 6.2 g/kg
Oral - rat LD50: > 10 g/kg [40, 42]; 17 g/kg [42]

Acute Exposure: PMPPI is practically non-toxic by dermal absorption and ingestion, as indicated by its relatively high oral LD50 of > 10 g/kg and dermal LD50 of > 9.4 g/kg. Short term overexposure to isocyanate vapors can cause eye, nose, and throat irritation; shortness of breath, wheezing, and chest pain or tightness. High aerosol concentrations may cause asthma-like wheezing, inflammation of the lungs, and fluid in the lungs (pulmonary edema), which could be fatal [40].

Chronic Exposure: Long-term, low-level exposure to PMPPI, a severe respiratory irritant, can cause permanent respiratory impairment. Respiratory sensitization can develop in isocyanate-exposed individuals, usually due to very large or multiple exposures. Symptoms may include severe asthmatic reactions immediately or several hours after exposure, and sensitivity may persist for several years after exposure ceases [40]. Sensitized individuals react to levels of MDI as low as 0.02 mg/m^3 that have no effect on unsensitized people [40]. Cross sensitization with MDI and other isocyanates is also possible [38].

Inhalation Exposure: The extremely low vapor pressure of PMPPI and PAPI® 2580 makes airborne exposures unlikely unless the material is heated or produces an aerosol or mist. Rats survived a single 8-hour exposure to 3.3 mg/m^3 (0.2 PPM) of PAPI® vapor with no significant toxicological effects. In another study, rats exhibited no adverse effects when exposed to PAPI® concentrations between 3.3 and 42.5 mg/m^3 (0.2 and 2.6 PPM) for 30 minutes/day, 5 days/week for 2 weeks [3]. Mild respiratory sensitization occurred in guinea pigs exposed to 4.6 mg/m^3 of commercial PMPPI 4 hours/day for 5 days [40]. In addition, a manufacturer's MSDS for PAPI® 2580 reported that unspecified lung injury had been observed in laboratory animals after multiple large exposures to MDI/PMPPI aerosol droplets [39].

Dermal Exposure: Dermal absorption is not considered a major route of exposure to PAPI® 2580, and the LD50 of 9.4 g/kg catagorizes it as practically non-toxic following dermal exposure [39]. However, skin irritation or staining may result from excessive or repeated exposure to PAPI® 2580 or PMPPI in general. Other symptoms may include inflammation, rash, blistering, and skin hardening [39, 40]. Only minor, reversible skin changes were seen for single-dose exposures of intact and abraded rabbit skin to PAPI® concentrations between 0.0025 and 0.0094 g/kg [3]. Skin sensitization to commercial PMPPI was reported in guinea pigs that had previously inhaled MDI [40].

Oral Exposure: An oral LD50 of > 10 g/kg for PAPI® [39, 43] or > 17 g/kg for PMPPI [42] classifies them as practically non-toxic or relatively harmless, respectively. However, weight loss was observed in rats at or below PMPPI concentrations of 11 g/kg [42].

Eye Exposure: The manufacturer's MSDS suggests that eye exposure to PAPI® 2580 may cause slight eye irritation, but permanent corneal injury is unlikely [39]. A study involving application of PAPI® to rabbit eyes produced minor, reversible corneal damage or an occasional discharge, which disappeared within 7 days after application [3].

Carcinogenicity: PAPI® 2580 is not listed as a carcinogen by NTP, IARC, ACGIH; or OSHA. [9, 39]. Rats exposed to respirable PMPPI concentrations of 1.0 and 6.0 mg/m^3 for 6 hours/day, 5 days/week for up to 2 years developed recurring lung tissue damage, and an increase in lung cancer was seen at 6.0 mg/m^3 [40]. See the following section on methylene bisphenyl isocyanate for information on potential MDI carcinogenicity.

Reproductive Effects: There are no known reproductive effects following exposure to PMPPI in general [38] or to PAPI® 2580 [39].

Flammability: PAPI® 2580 and PMPPI are considered slight fire hazards when exposed to heat or flames. The greatest hazard arises from the possible release of toxic gases (see Hazardous Decomposition Products below). PMPPI is classified as an OSHA Class IIIB combustible liquid (flash point at or above 200° F) with NFPA ratings of 3 for health (materials which could cause serious temporary or residual injury after short exposure even with medical treatment), 1 for flammability (materials which must be preheated before ignition can occur), and 1 for reactivity (materials which are normally stable but may react or decompose in the presence of water or elevated temperatures or pressures) [38].

Incompatibility: PMPPI and PAPI® 2580 can react with water to generate enough heat and pressure to rupture a closed container. Temperatures greater than 120° F (49° C) accelerate the reaction, as do acids, bases, amines, alcohols, metal compounds and organotin compounds, and surface-active agents. Polymeric MDI may corrode aluminum and copper (alloys) and embrittle plastics and rubbers [38, 39].

Hazardous Decomposition Products: Thermal decomposition of polymeric MDI materials such as PAPI® 2580 may produce an isocyanate vapor or mist, oxides of carbon and nitrogen, and traces of highly toxic hydrogen cyanide [38, 39].

Personal Protective Equipment: When using PMPPI or PAPI® 2580, splash-proof or other appropriate safety goggles and a face shield, compatible chemical-resistant gloves, and appropriate protective clothing to prevent repeated or prolonged skin or eye contact and possible sensitization are recommended. Suitable materials for use with MDI include polyvinyl alcohol, nitrile rubber, butyl rubber, and polyvinyl chloride (PVC) [40].

Under conditions that may generate an airborne exposure, the need for respiratory protection should be determined by air monitoring. When respiratory protection is necessary, a NIOSH/MSHA-approved respirator is recommended. Selection of the appropriate equipment must be based on the the specific operation and on the contamination levels encountered at the site. For protection from airborne exposure, follow the respirator recommendations for MDI contained in the following section.

Methylene Bisphenyl Isocyanate

Chemical Name [44]:
Methylene bisphenyl isocyanate
4,4'-Methylenediphenyl diisocyanate
MDI

Molecular Formula [45]:
$CH_2(C_6H_4NCO)_2$

CAS Number:
101-68-8

Chemical and Physical Properties [44]:
Appearance: Yellow, fused solid or white crystals
Odor: May have a slightly musty odor. Odor threshold 0.4 PPM, method unspecified [46].
Vapor Pressure: 0.01 mm Hg at 68° F (20° C) [44] or 0.00014 mm Hg at 77° F (25° C) [46] or 0.000005 mm Hg at 77° F (25° C) [47]
Specific Gravity: 1.2
Melting Point: 99° F (37° C)
Boiling Point: 597° F (314° C) [44]. Decomposes or polymerizes at about 450° F (232° C) [46].
Flash Point: 385° F (196° C), OC

Exposure Limits: The following occupational exposure limits have been established for MDI [9, 44]:

OSHA PEL:	Ceiling 0.2 mg/m^3 (0.02 PPM)
NIOSH REL:	TWA 0.051 mg/m^3 (0.005 PPM)
	10-Minute Ceiling 0.2 mg/m^3 (0.02 PPM)
ACGIH TLV:	TWA 0.051 mg/m^3 (0.005 PPM)

Toxicology:

Inhalation - rat LC50: 369–490 mg/m³ for a 4-hour aerosol exposure [46]
Dermal - rabbit: 0.5–0.6 g dose for 24 hours caused slight to moderate irritation [44, 46]
Dermal - rabbit LD50: > 10 g/kg [43] or > 7.9 g/kg [44]
Oral - rat LD50: >10 g/kg [43]
Oral - mouse LD50: 2.2 g/kg [44]
Eye, Standard Draize test - rabbit: 100 µg dose was mildly irritating [46]

Acute Exposure: MDI is considered extremely toxic by inhalation and practically non-toxic by ingestion or dermal absorption. Short-term exposure to low concentrations may cause respiratory, dermal, or eye irritation. Higher concentrations can result in allergic reactions, breathing difficulties, gastrointestinal disturbances, and possibly death [44].

Chronic Exposure: Large or continued respiratory exposures to MDI can produce allergic sensitization, usually within the first few months of exposure. Symptoms vary from nocturnal breathing difficulties and mild cough to severe asthmatic bronchitis. Cross sensitization between different isocyanates may also occur; that is, someone sensitized to MDI may show an allergic response to another isocyante upon initial exposure. Sensitivity and continued respiratory problems may persist for several years after exposure ceases [44, 46].

Inhalation Exposure: The vapor pressure of MDI at 68–77° F (20–25° C), as reported in the literature, varies from from 0.000005 [47] to 0.01 [44] mm Hg. The low vapor pressures suggest that inhalation of MDI vapor is an unlikely route of exposure except at extremely high temperatures. Inhalation exposure is most likely to occur with an aerosol or mist. The LC50 of 369–490 mg/m³ for a 4-hour aerosol exposure classifies MDI as a highly toxic inhalation hazard. MDI workers have developed respiratory sensitization, usually after very large or multiple exposures. Subsequent exposure to isocyanates may result in severe asthmatic symptoms which include wheezing, chest tightness, shortness of breath, and accumulation of fluid in the lungs. Exposure of mice for 4 hours to MDI concentrations of 7–59 mg/m³ resulted in diminished respiratory capacity. The measured RD50, the concentration required to reduce the respiratory rate by 50%, was found to be 32 mg/m³. This response was attributed to pulmonary irritation from exposure to MDI [46].

Dermal Exposure: Dermal contact with isocyanates can cause skin discoloration, hardening, and skin sensitization leading to dermatitis after repeated exposures. Rabbit studies indicated slight to moderate irritation from a 24-hour application of 0.5 ml of MDI [46]. The dermal LD50 concentration of > 7.9 g/kg indicates that MDI is practically non-toxic via skin absorption [44]. However, sensitization due to dermal exposure can result in a severe asthmatic condition following subsequent inhalation exposure.

Oral Exposure: Ingestion of MDI has shown only slight adverse effects, including possible irritation of the gastrointestinal tract with nausea, vomiting, and abdominal spasms [44]. An LD50 of > 10 g/kg places it in the catagory of practically non-toxic by ingestion. However, rats given 5 daily oral doses of 4.3–5 g/kg showed slight enlargement of the spleen in 40% of the exposures [43, 46].

Eye Exposure: Acute exposure to MDI may cause irritation, redness, pain, and blurred vision, while repeated or prolonged contact may cause inflammation of the lining of the eyelids [44]. Rabbit eyes exposed to 0.1 mg of MDI (1 mg of a 10% solution) experienced mild inflammation and tearing. In a separate study, application of 120 mg (0.1 ml) of MDI produced reversible lesions, abrasions, and inflammation of the cornea [43, 46].

Carcinogenicity: MDI is classified as an IARC Group-3 carcinogen, that is, one for which evidence of human and animal carcinogenicity is inadequate. Ames tests of MDI for mutagenicity using several strains of Salmonella typhimurium demonstrated both negative and weakly positive results, while a mutagenicity study in animals was negative [43, 46]. However, MDA (4,4'-methylenedianiline, CAS 101-77-9), a potential intermediate in the reaction of MDI with water from PAPI, is classified as IARC Group-2B (possibly carcinogenic to humans)/NTP Group 2B (anticipated human carcinogen)/ACGIH TLV-A2 (suspected human carcinogen) [9]. Studies with MDA have indicated the development or enhancement of various liver, kidney, uterine, and thyroid tumors in rats and mice [44, 46].

Reproductive Effects: There are no known reproductive effects following exposure to MDI [43, 46].

Flammability: MDI is considered a slight fire hazard when exposed to heat or flames. The greatest hazard arises from the possible release of toxic gases (see Hazardous Decomposition Products below). The NFPA ratings are 4 for health (materials which could cause death or permanent injury after very short exposure even with medical treatment), 1 for flammability (materials which must be preheated before ignition can occur), and 0 for reactivity (materials which are normally stable, even during exposure to fire or water) [44].

Incompatibility: MDI undergoes uncontrolled polymerization upon contact with strong bases, acids, alcohols, amines, organometallics, and surface-active compounds or if heated above 399° F (204° C). Reaction with water proceeds slowly below 122° F (50° C), but the reaction becomes progressively more vigorous at higher temperatures (see Hazardous Decomposition Products below). MDI may also attack and embrittle many plastics and rubbers [44, 46].

Hazardous Decomposition Products: Thermal decomposition of MDI may produce carbon monoxide, carbon dioxide, nitrogen oxides, and highly toxic hydrogen cyanide fumes [44]. Reaction with water is reported to produce 4,4'-methylenedianiline (MDA) as an intermediate in the final production of nontoxic polyureas [46]. MDA is a liver toxin and a suspected human carcinogen (see Carcinogenicity above).

Personal Protective Equipment: When using pure methylene bisphenyl isocyanate, splash-proof or other appropriate safety goggles and a face shield, compatible chemical-resistant gloves, and appropriate protective clothing to prevent repeated or prolonged skin or eye contact are recommended. Materials which may be suitable for protective clothing include polyvinyl alcohol, nitrile rubber, butyl rubber, and polyvinyl chloride (PVC) [46].

Under conditions that may generate an airborne exposure, the need for respiratory protection should be determined by air monitoring. When respiratory protection is necessary, a NIOSH/MSHA-approved respirator is recommended. Selection of the appropriate equipment must be based on the the specific operation and on the contamination levels encountered at the site. For protection from airborne exposure, the following respirators and their maximum use concentrations are recommended [44]:

2 mg/m^3	Any supplied-air respirator
5 mg/m^3	Any supplied-air respirator operated in continuous-flow mode
10 mg/m^3	Any SCBA with a full facepiece
100 mg/m^3	Any SCBA with a full facepiece, operated in a positive-pressure mode. This concentration is considered immediately dangerous to life or health (IDLH).

Conclusions

The two rigid foams evaluated in this document are expected to present comparable toxicities. The components are mixed completely before pouring, and the small quantities used are designed to react completely. Once fully deployed to encapsulate the ordnance, the foams should present no significant health hazard.

The hazards listed in this document are those anticipated for the use of large quantities of the individual components. Use of either rigid foam kit should present a low risk of adverse effects because of the small quantities being used; the relatively low toxicity of most of the components; the low vapor pressure of the constituents, which results in relatively low risk of air contamination; and the minimal amount of handling of the unreacted components.

Recommendations for personal protective equipment when using the kits will depend on the environment in which the project takes place. When used in a well-ventilated area, for example, outdoors, in a large building like a hanger, or where mechanical ventilation is available, skin protection such as gloves and eye protection such as safety goggles should be sufficient. In a more confined area, such as an unventilated storage bunker or aircraft bomb bay, or at higher than ambient temperatures, respiratory protection may be required in addition to skin and eye protection. Determination of the need for respiratory protection and a recommendation regarding the type of respirator needed will require an exposure evaluation by the Industrial Hygienist assigned to the organization.

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