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TOXIC MATERIAL ADVISORY REPORT

2-MERCAPTOETHANOL

N.M. Bernholc, O. White, Jr., R.S. Baloyi, and B.D. Silverstein

March 1983

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CENTER FOR ASSESSMENT OF CHEMICAL AND PHYSICAL HAZARDS
SAFETY AND ENVIRONMENTAL PROTECTION DIVISION

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

UNDER CONTRACT NO. DE-AC02-76CH00016 WITH THE
UNITED STATES DEPARTMENT OF ENERGY

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I. SUMMARY RECOMMENDATIONS

A. Recommended Interim Exposure Limit for 2-Mercaptoethanol

An interim exposure limit (IEL) of 0.5 ppm is recommended for an average concentration exposure to employees during an 8-hour work shift. A review of the 2-mercaptoethanol (2-ME) toxicity literature and a comparison to structurally similar compounds were made. Decreased oxygen consumption, lymphopenia, and neutrophilia were found in rats chronically exposed to 6 mg/m³ (1.9 ppm) 2-ME. The threshold limit values (TLV) for the structurally similar compounds ethanethiol, methanethiol, and butanethiol were based on odor and irritation discomfort to human volunteers, rather than toxicity. Acute toxicity studies suggest 2-ME may be more toxic than butanethiol, ethanethiol, and methanethiol by the oral exposure route, while it may be comparable to propanethiol, but less toxic than ethanethiol and butanethiol by inhalation exposure. Since 2-ME has many toxic effects and an odor threshold comparable to the thiols discussed, the IEL was set at a level equal to those thiols, and below the level where systemic changes were found in rats.

B. Monitoring and Analysis

No effective sampling method has been identified for 2-ME. NIOSH has suggested that sorbent tubes containing Chromosorb 104 should be an efficient sampling method for thiols, though it has been found unsatisfactory for ethanethiol. Gas chromatographic techniques have been used to detect thiols in the parts per billion range, and a gas chromatographic methodology for 2-ME has been identified and is recommended.

C. Work Practices and Controls

2-Mercaptoethanol should be used in a closed system, under a laboratory hood or with local exhaust ventilation. Protective clothing including impervious rubber gloves, aprons, and boots, as well as eye protection and respiratory protective equipment should be worn where concentrations may exceed the IEL, i.e., during nonroutine operations, repair activities, maintenance activities, or emergencies. Eyewash fountains and emergency showers should be available in the area, since 2-ME is a skin and mucous membrane irritant.

2-ME should be stored separately from mineral acids, oxidizing agents, and dry hypochlorite. Containers of 2-ME should be labeled with the name of the product and information on adverse health effects from exposure to the compound on human health. First-aid and use instructions should be included.

Since 2-ME is moderately flammable, standard precautions for flammables should be followed. In the event of a fire, use carbon dioxide, water spray, alcohol foam, or dry chemical fire extinguishers can be used. Personnel should have self-contained breathing apparatus readily available. In the event of a spill, all ignition sources should be eliminated. Unnecessary personnel should be cleared from the area.

D. Medical Surveillance Program

Medical surveillance of all workers exposed to 2-ME should be conducted. This should take the form of preplacement and periodic medical examinations tailored to identify adverse effects from 2-ME exposure. Records should be retained for at least 30 years post-employment.

E. Research Needs

Research is needed to develop 2-ME direct reading equipment as well as sampling equipment designed to collect area and personal samples. Research

should also be directed towards the development of effective desorption procedures for 2-ME chromatographic analysis and the identification of proper 2-ME sorbents for sample collection. Animal studies in several species are needed to evaluate the acute and chronic inhalation effects of 2-ME, the metabolism of 2-ME, and its carcinogenic and mutagenic potentials. Epidemiology studies directed towards the long term effects of 2-ME are also needed.

II. INTRODUCTION

The Center for Assessment of Chemical and Physical Hazards was established by the Department of Energy (DOE) to facilitate the development of interim exposure guidelines for chemical and physical occupational and environmental hazards which are associated with DOE activities. The information used to establish the interim guidelines for individual exposure to 2-mercaptoethanol (2-ME) including an exposure limit, was obtained from published literature, manufacturers and users of 2-ME. The internal guidelines recommended in this report are prepared for DOE and its contractors to provide appropriate health protection where no guidelines have been established by the standards-setting agencies or organizations.

III. BIOLOGICAL EFFECTS OF EXPOSURE

A. Extent of Exposure

2-Mercaptoethanol (2-ME), molecular formula $\text{HSCH}_2\text{CH}_2\text{OH}$, is a white mobile liquid with a strong unpleasant odor. The odor threshold of thiols (i.e. mercaptans) is between 0.7 and 35 ppb.¹ 2-ME has a vapor pressure of 1.0 mm/Hg at 20°C and a boiling point of 157.1°C. A detailed physical and chemical description of the properties of 2-ME can be found in Table 1. It is manufactured by reacting ethylene chlorohydrin with sodium hydrogen sulfide, or by reacting ethylene oxide* with hydrogen sulfide.²

Mr. D. Hensel of NIOSH³ reported that 38,750 workers in the United States are potentially exposed to 2-ME. 2-ME is used as an initiator for polymeric reactions, a reagent for diagnostic bioassays, a rust inhibitor for steel, a brightening agent in copper deposition, a tarnish remover from alloys and metals, an ingredient in hair permanent chemicals and hair and wool dyes, a stabilizer, and a mosquito control agent.⁴

B. Effects on Humans

2-ME is extremely irritating to skin, eyes, and mucous membranes, and may cause the development of contact dermatitis and pulmonary edema. Like other thiols, 2-ME may depress the central nervous system and cause respiratory paralysis and death. The literature contains no information on human long-term or short-term exposure to 2-ME. The Center for Disease Control in Atlanta has one recorded case of an accidental spill of 2-ME, with no ill effects reported to exposed individuals.⁵ Phillips Petroleum Company, manufacturer of 2-ME, has no record of acute exposure to the chemical, but considers 2-ME a severe eye irritant.⁶

*In light of recent findings on ethylene oxide, manufacturers should be aware of possible exposure to employees.

C. Effects on Animals

1. Acute Exposure Studies

Pugaeva et al.⁷ conducted a series of acute and chronic toxicity tests for the purpose of collecting toxicity data to be used in establishing a hygienic standard for the Soviet Union. The lethal dose (LD) value of 2-ME by single intragastric injection (ig) was determined for white mice and male albino rats (strain not specified). The lethal concentration of 2-ME in mice was determined in a two-hour static inhalation exposure. The ig values reported were as follows: For mice, the $LD_{16} = 73.4$ mg/kg, $LD_{50} = 190$ (160-219) mg/kg, and $LD_{84} = 392$ mg/kg. For rats the $LD_{16} = 109$ mg/kg, $LD_{50} = 224$ (185-268) mg/kg, and $LD_{84} = 526$ mg/kg. For the inhalation study, lethal concentrations for mice were $LC_{16} = 7,800$ mg/m³ (2,445 ppm), $LC_{50} = 13,200$ (10,800-15,500) mg/m³ (4,138 ppm), and $LC_{84} = 20,400$ mg/m³ (6,395 ppm). The authors did not specify the operating temperature within the inhalation chamber. It should be noted that the vapor pressure and corresponding temperature required to obtain the concentrations used in the inhalation chamber experiments represent conditions that are not optimal for animal survival (Table 2).

In the first 15 to 20 minutes following intragastric (ig) administration to mice and rats, signs of intoxication appeared in the form of motor unrest followed by respiratory suppression, disturbed motor coordination, and tonoclonic seizures. In animals dying on the second day following ig administration, small drop fatty degeneration of the liver cells and stasis in the kidney, spleen, lungs, gastric mucosa, and the small intestine were observed.

Inhalation of 2-ME resulted in a prolonged stage of adynamia. Central nervous system depression with spasms and animals lying on their backs occurred just before death due to respiratory failure. Microscopic examination of internal organs of animals that inhaled lethal concentrations but survived 14 days indicated lymphocyte infiltration of the liver and kidney, destruction and hemorrhaging of the lungs, and foci inflammation of the myocardium.

In a 4-hour dynamic inhalation experiment in which three groups (six animals per group) of male albino rats were exposed to 10 or 6 mg/m³. Pugaeva et al.⁷ reported that a 2-ME concentration of 10 mg/m³ caused a depression of the threshold of neuromuscular stimulation and an increase in work performance. Six mg/m³ caused no significant changes.

Pugaeva et al.⁷ also studied local irritation and general toxic effects of 2-ME by applying it to the depilated skin of rabbits (two hours per day for ten days) and the skin of mice by immersing two-thirds of their tails in the substance for each experiment. Seven groups containing six animals each were used. The appearance of diffuse hyperemia of the skin and foci petechial bleeding was noted following the first 2-hour exposure in rabbits and mice. Repeated application in rabbits caused the development of a hemorrhagic crust surrounded by an edematous and hyperemia zone. This damage healed within 25 days after cessation of exposure.

Pugaeva et al.⁷ also reported that when 2-ME was applied to the skin of mice, it caused death. The lethal time (LT) values for this "reabsorptive lethal effect" were LT₁₆ = 4.3 min; LT₅₀ = 18 min (15-21.6 min); LT₈₄ = 80 min.

While this paper provided information regarding the effects of 2-ME, Pugaeva et al.⁷ did not present information on strain of animals used or on animal treatment prior to exposure. The authors also did not present information regarding inhalation chamber temperature conditions during the static two-hour inhalation studies and dynamic inhalation exposure studies.

White et al.⁸ conducted oral and intraperitoneal LD₅₀ experiments on male Swiss-Webster albino mice. In the oral intubation experiments, food was withheld for 24 hours before testing. Animals were observed during the post injection period of 24 hours for toxic symptoms and for 14 days for fatalities. Both routes of administration yielded essentially the same LD₅₀ values (322 mg/kg intraperitoneal and 348 mg/kg oral administration). Central nervous system effects noted were similar to those described by Pugaeva et al.⁷

In another experiment, White et al.⁸ conducted a four-week study of 2-ME exposure on male Swiss-Webster albino mice. Two groups of 15 mice were given daily intraperitoneal (ip) doses of 2-ME for five consecutive days of each week. One group received a dose of 161 mg/kg and the other group received a dose of 80.5 mg/kg. A third control group received normal saline. All 2-ME-treated mice died within the four-week study period. After eight days, seven mice died in the 161 mg/kg group. A progressive depression of the central nervous system was observed.

White et al.⁸ also evaluated the irritation potential of varying concentrations of 2-ME to skin on male New Zealand albino rabbits. In all cases, 20% ethanol was used as a positive control and normal saline was used as a negative control. Exposures were evaluated 24 hours and 72 hours after application.

Primary irritation was evaluated by topical application to abraded and unabraded sites on the shaved back of one rabbit. Only in the undiluted form was a significant degree of edema observed. Dilutions provided only temporary irritation on abraded skin and slight reaction on normal skin. Undiluted 2-ME was moderately irritating to both normal and abraded skin and the duration of irritation was transient on normal skin, but prolonged on abraded skin. Skin irritations from 2-ME did not heal as quickly as equally severe ethanol reactions.

In the same experiment, intracutaneous injection of 0.2 ml 2-ME was evaluated over a three-day period on two male New Zealand rabbits beginning one hour post injection and at 24-hour intervals thereafter. Within one hour of injection, doses of 100% 2-ME, and 20%, 10%, and 2% 2-ME in normal saline solution produced a severe (beet red) erythema with a blanched center and necrosis at the site of injection. After two hours, slight recovery was present only with the 2% concentration. A concentration of 1% produced a delayed distinct irritation after 24 hours, which disappeared by the end of the 72-hour observation period.

White et al.⁸ also evaluated ocular irritation of 2-ME on two groups of six New Zealand albino male rabbits, at intervals of 1, 24, 48, and 72 hours following exposure for an unspecified time with undiluted solutions of 2-ME and 20% solutions of 2-ME in normal saline. Groups of six rabbits were also treated with identical dilutions of ethanol. Controls were exposed to saline solution, and no irritating effects were observed. Undiluted 2-ME produced severe redness and chemosis of the conjunctiva and moderate, but prolonged, corneal scarring and opacity after four months. The undiluted 2-ME

also affected the surrounding mucosa, demonstrated by complete loss of hair in the periocular area. When compared to 95% ethanol, undiluted 2-ME was twice as potent. Dilution of both substances reduced the irritation potential of both compounds. A 20% solution of 2-ME caused only slight irritation. No injurious effects were caused by further dilutions.

In another experiment by White et al.⁸, penile mucosa irritation was tested on rabbits by placing a 0.2-ml solution of 100% 2-ME in contact with mucosal tissue for 1 minute. Within 24 hours, severe erythema, moderate edema, and scabbing developed on the penile mucosa and necrotic lesions developed on the scrotum which was contacted accidentally during application. As in the ocular irritation study, concentrations of 20% produced further transitory erythema and edema.

Smyth and Carpenter⁹ did a range-finding assessment of 2-ME toxicity. The oral LD₅₀ in male albino Wistar rats was 0.3 g/kg and the topical range-finding LD₅₀ for guinea pigs was 0.3 ml/kg (approximately 0.33 g/kg). Smyth and Carpenter⁹ also observed the irritation potential of 2-ME on rabbit skin and eyes. They found that 2-ME produced epidermal irritation similar to that produced by morpholine and rabbit corneal toxicity equivalent to that produced by butyl alcohol; however, no data were given to support the comparison.

In an unpublished oral toxicity study on rats by Phillips Petroleum Company⁶, it was reported that 1 of 14 young adult albino Sprague-Dawley rats (7 male and 7 female) died within 2 days of receiving a single dose of 50 mg/kg by gavage. The investigators concluded that 2-ME is not a Class B poison (as defined by DOT¹⁰) when administered by the oral route.

In a separate experiment, Phillips Petroleum Company investigators evaluated skin corrosivity and primary irritation properties of 2-ME on 4 male and 3 female adult New Zealand white rabbits.⁶ A dose of 0.5 ml 2-ME was applied to a one square inch gauze pad and secured to the shaved backs of the rabbits. Four hours after application, the test sites were wiped dry. The primary skin irritation index was determined as 3.4 (maximum possible score is 4), and no evidence of corrosivity was observed.

The investigators also reported the effects of 2-ME application to rabbit eyes.⁵ In one experiment, 0.1 ml undiluted 2-ME was placed in the conjunctival sac of the right eye of 7 adult New Zealand white rabbits. The left eye served as a control. The eyelids were gently held closed for 1 second and then released. Animals were observed for 35 days. A maximum average eye irritation score of 60.1, as calculated by the Draize method,¹¹ was observed at 14 days. The investigators concluded that 2-ME is a primary eye irritant especially to the unwashed eye. In a separate experiment on 6 New Zealand white rabbits⁶ 0.1 ml of 2-ME was placed in the conjunctival sac of the right eye, and the eyelid was gently held closed for 4 seconds. The eye was then washed out with lukewarm tap water delivered with a 60-cc syringe for 13 to 19 seconds. A maximum average eye irritation score of 33.6 as calculated by the Draize method was observed at 24 hours. The authors concluded that washing 2-ME out of the eye reduces the degree of irritation caused by the material.

2. Chronic Studies

Pugaeva et al.⁷, reported the effects of long-term inhalation exposure of rats to 2-ME. Two groups of 20 male albino rats were exposed to

10 mg/m³ for 6 months. Twenty control rats received no exposure. The authors did not mention duration of daily exposures. Concentrations were monitored quantitatively by spectrophotometric methods. Animals were weighed every 10 days; liver function and arterial pressure were measured bimonthly; and composition of peripheral blood, protein spectrum of blood, oxygen consumption, and inorganic and organic sulfur metabolism (determined by urine analyses) were measured once a month. An examination of the animals' internal organs was made upon conclusion of the experiment.

For rats exposed at 10 mg/m³, in the third month, the authors first observed neuromuscular depression, lymphopenia, neutrophilia, and decreased oxygen consumption. In the fifth month, increased organic sulfate elimination; and variation in weight, arterial pressure, liver function, and protein metabolism were observed. Protein destruction of liver tissue was found upon histological examinations.

Less pronounced changes in oxygen consumption, neutrophil, and lymphocyte count were observed in animals exposed at 6 mg/m³. No significant change in sulfur metabolism and no pathological changes in internal organs occurred. The authors speculated that 6 mg/m³ may be close to the threshold for prolonged exposure. They concluded that a concentration of 1 mg/m³ (0.3 ppm) should be established for the Soviet Union as the maximum permissible concentration (MPC) for 2-ME for air in the workplace.

3. Metabolism Studies

Sabourault et al.¹² conducted a series of comparative experiments to determine if sulfhydryl compounds induced fatty liver in rats. GFR female Wistar rats were fasted overnight and 2-ME (40 µM/100 g body weight or

0.016 mg/kg) was administered intraperitoneally as a single dose of a 40 mmole/l aqueous solution, 2-mercaptopropionate, or 2-mercaptoacetate. Control rats received an equal volume of saline solution. Animals were killed by decapitation 3, 6, 8, 18, 24, 30, and 48 hours after administration of 2-ME.

Results indicated that 2-ME induced a fatty liver condition as shown by a significant rise (three times the controls) in liver triacylglycerol and blood-free fatty acid levels, a slight but nonsignificant reduction of liver phospholipids, and a progressive decrease of blood triacylglycerol (25%) and blood phospholipid levels (30%) as well as a reduction of hepatic ketone body levels. Both the blood triacylglycerol and blood phospholipid levels were similar to control values by the 34th hour. 2-Mercaptoacetate induced effects similar to those produced by 2-ME on the liver and blood. The authors concluded that not all sulfhydryl compounds induced a fatty liver condition. They also speculated that the induced fatty-liver condition is a result of increased peripheral fat mobilization, as well as decreased hepatic lipoprotein synthesis and/or release. Sabourault speculated that 2-ME is metabolized in vivo and that 2-mercaptoacetate may be the intermediate responsible for the fatty liver condition. Speculation was drawn from the studies by Lambe et al. who have shown that 2-ME can lead in vitro to 2-mercaptoacetate through the combined effect of alcohol dehydrogenase and aldehyde dehydrogenase.¹³

In a subsequent study, Sabourault et al.¹⁴ further investigated the mechanism of action of 2-ME on the induced fatty liver by studying the effect of alcohol dehydrogenase inhibition. Female Wistar rats were used following the same protocol as in the previous study.¹² Inhibition of alcohol

dehydrogenase was induced by an intraperitoneal injection of pyrazole at a dose of 27 mg/100 g body weight ten minutes before administration of 2-ME or 2-mercaptoacetate. Inhibition by pyrazole of alcohol dehydrogenase almost completely prevented the elevatory effects of 2-ME on liver triacylglycerol and blood free fatty acid level seen at three hours or eight hours after treatment, but had no effect on 2-mercaptoacetate-induced elevations in these parameters. The author concluded that 2-ME conversion to 2-mercaptoacetate by alcohol dehydrogenase may have been inhibited by pyrazole and suggested that 2-mercaptoacetate may be responsible for fatty liver induction.

In another study, Sabourault et al.¹⁴ investigated the effects of 2-mercaptoethanol and 2-mercaptoacetate on the lipolytic activity of female Wistar rat adipose tissue. 2-ME and 2-mercaptoacetate increased the fatty acid released by 110% and 140%, respectively. Pyrazole suppressed the stimulating effect of 2-ME on free fatty acid release; however, it did not alter the effects of 2-mercaptoacetate. Glycerol release was unaffected by 2-ME, but 2-mercaptoacetate produced a statistically significant increase. The adenosine triphosphate (ATP) level in adipose tissue was depressed 54% by 2-ME and 60% by 2-mercaptoacetate.

Nordmann and Nordmann¹⁵ found that 2-ME increased liver triglycerides and plasma-free fatty acid in female Wistar rats which received two intraperitoneal injections of 2-ME. Significant decreases in liver glycogen, blood glucose, and blood ketones as well as a drop in total ketones and a drop in the B-hydroxybutyrate/acetacetate ratio in the blood were also observed which are similar to effects produced by inhibitors of fatty acid oxidation, e.g., hypoglycin, pent-4-enoic acid, and cyclopropane carboxylic acid. The

authors concluded that 2-ME probably inhibits both hepatic oxidation of fatty acids and ketogenesis but does not inhibit the extrahepatic utilization of ketones. In another experiment,¹⁶ Nordmann confirmed this finding when it was demonstrated that 2-ME reduced liver ketogenesis by almost 90% and decreased palmitate oxidation by 40%.

Other studies have found that 2-ME inhibited rat thymus deoxycytidine formation,¹⁷ inhibited mitotic activity in the rat intestine,¹⁸ inhibited thymidine incorporation in rat DNA,¹⁸ and caused moderate deoxyribonuclease inhibition.¹⁹

4. Cytogenetics Studies

There are many studies which indicate that 2-ME has a potential for long-term effects on cell growth. These effects may include polyploidy induction,²⁰ cellular degeneration,²¹ induction of mitogenic response in T and B cells,²² and increased fibrogenolytic activity.²³

While the data indicated the potential for adverse 2-ME effects, the concentrations used to promote the effects approach the lethal concentration for cells. Extrapolation of the data presented in these studies to human workplace exposures is difficult.

5. Teratogenic and Embryo Toxicity Studies

Mueller and Skreb²⁴ investigated the effect of 2-ME on white rat embryo development. Twice daily, pregnant rats received intraperitoneally 0.007 g/200 g (35 mg/kg) of 2-ME. The number of controls and the length of time that the animals received 2-ME doses were not specified. Another set of animals received progesterone (2.5 or 5 mg/200 g) once daily in addition to the 2-ME injections in order to promote mucosal growth. In both cases, animals were killed on the 12th or 15th day of pregnancy.

Results from the intraperitoneal injection of 2-ME alone showed that increasing duration of 2-ME administration to females greatly reduced successful embryo implantation. Embryos that survived the 2-ME-treatment weighed significantly less than the controls while daily progesterone administration greatly increased the number of females with embryos, but no increases in embryo weights over 2-ME only treated females were noted.

Histological examination of preparations from 2-ME-treated pregnant rats revealed necrosis of the uterine mucosa and inhibition of mitoses. Embryo resorption was a secondary phenomenon. Two deformities out of 460 cases were observed. Embryos that survived were lighter in weight and retarded in development, than controls in both cases, regardless of whether progesterone was administered or not. While teratogenic effects occurred, control data results were not presented and results were not compared to the natural background abnormality rate.

In studies by Mazia²⁵ and Mazia and Zimmerman²⁶ on amphibian eggs, a critical level of 0.075 M 2-ME blocked the mitotic process at any stage of development. This blockage resulted in the production of twins or quadruplets. Subcritical levels of 2-ME produced a delay in the mitotic process. These findings were confirmed by Brachet^{27,28}, and Malpoix et al.²⁹ who also found a blockage of the gastrulation process in amphibians.

D. Structurally Similar Compounds

A summary of the structures and physical and chemical properties of compounds structurally similar to 2-ME can be found in Tables 3, 4, and 5. Comparisons of toxicity data are presented in Tables 6 to 9. Structural similarity was based on compounds having both the SH and OH groups. Both

thioglycerol and 2,3-dimercaprol have these characteristics. Methanethiol, ethanethiol, propanethiol, and butanethiol have the SH functional group alone. In rats, 2-ME is more toxic than ethanethiol, propanethiol, and butanethiol by the oral route [6.5 times more than ethanethiol, 6 times more than propanethiol, and 2.3 times more than butanethiol (Table 7)]. In mice by the intraperitoneal route, thioglycerol appears to be between 1.2 to 2 times as toxic as 2-ME, while 2,3-dimercaprol appears to be 8 times more toxic than 2-ME (Table 6). By the inhalation route in mice, 2-ME is equally toxic as propanethiol, but less toxic than butanethiol and ethanethiol (Table 9).

Other acute, chronic, and exposure limit data for the compounds are as follows:

For thioglycerol³⁰, no additional acute and chronic information is available. Its industrial uses are very similar to those of 2-ME: as ingredients in cold permanent waves, as a stabilizer for acrylonitrile polymer, in pharmaceuticals, and as a bioassay reagent.^{31,34} It appears that thioglycerol acts as a sensitizer and can produce contact dermatitis with edema, burning, itching, and erythema.^{32,33} Some indications of pathological changes in the thyroid have also been reported.³⁰ No standards of exposure currently exist for thioglycerol.

The compound 2,3-dimercaprol, more commonly known as BAL, is used as a chelating agent. While it seems to produce central nervous system (CNS) and cardiovascular effects, its use in treating heavy metal poisoning outweighs its negative effects.³⁰ Overdoses in children (40.5 mg/kg; 25.0 mg/kg repeated in four hours) resulted in vasomotor changes, hypertension, convulsions, and coma with recovery within one hour after onset of convulsions.

There is some indication that in humans a portion of dimercaprol may be excreted as a glucuronide.³⁰ While there is no occupational exposure standard for BAL, the recommended dose for treatment of heavy poisoning is 2 to 5 mg/kg.

Autopsies performed on animals surviving near-lethal ip or oral doses of thiols frequently exhibited microscopic changes indicative of damage to the liver and kidneys (similar to 2-ME). Rats and mice that die several hours after exposure at high concentration of thiol vapors had mild-to-severe hyperemia of the trachea and lungs. Microscopic changes included cloudy swelling, fatty degeneration, and necrosis of the liver; capillary engorgement, patchy edema, and occasional hemorrhage in the lungs; and mild-to-moderate cloudy swelling in the kidneys.

In summary, the general signs of acute thiol poisoning exhibited by mice, rats, and rabbits were CNS depression and respiratory paralysis, with death caused by respiratory failure.³⁴ Inhalation, ip, and oral administration at relatively high levels caused liver and kidney damage. Inhalation of thiols at high concentrations caused slight-to-severe irritation of the respiratory tract, the degree being dependent on the thiol.

The original basis for exposure to methanethiol, ethanethiol, and butanethiol was analogy with hydrogen sulfide.³⁴ Methanethiol was regarded as producing an acute toxicity similar to but less severe than that produced by hydrogen sulfide. Ethanethiol was regarded as being only one tenth as toxic as hydrogen sulfide, but reports of headache, nausea, and irritation experienced by humans at levels approaching 10 ppm led the ACGIH to propose and adopt a ceiling concentration of 10 ppm for ethanethiol. For butanethiol,

the odor was considered to be similar to that of hydrogen sulfide, and a TLV of 10 ppm was proposed. In the notice of intended changes for the 1968 TLV list, the ACGIH proposed 0.5 ppm as the TLV for butanethiol, ethanethiol, and methanethiol. These levels were adopted by ACGIH in 1970 and are still in effect today.

The justification for selecting these levels is as follows: Methanethiol was cited as being similar to hydrogen sulfide in toxicity but with a stronger more disagreeable odor. For ethanethiol, the TLV of 0.5 ppm was based on the effects in humans - headache, nausea, and irritation, at exposures of 4 ppm for three hours a day. For butanethiol, the TLV of 0.5 ppm is based on its readily noticeable odor at 0.1 to 1.0 ppm.

The current OSHA limits are based on the ACGIH adopted values for 1968. Austria, Belgium, Finland, Switzerland, and Yugoslavia have established limits for methanethiol, ethanethiol, and butanethiol of 0.05 ppm. The Netherlands only has limits for methanethiol and butanethiol at 0.5 ppm, and the Federal Republic of Germany sets a limit for ethanethiol at 0.5 ppm.

E. Summary

Acute exposure studies on 2-ME have been reviewed.⁶⁻⁹ A summary of inhalation and ingestion animal exposure data is given in Tables 6 and 11. Oral toxicity data suggest that 2-ME may be more toxic than structurally similar compounds by a factor of (2.3 to 6.5) may be comparable in toxicity to propanethiol by the inhalation route, but less toxic than ethanethiol and butanethiol (Tables 6 to 9). Single-dose topical application of pure 2-ME to eyes and skin of rabbits produces ocular and dermal irritation.⁵⁻⁸ It is concluded from the data on chronic exposure studies that the adverse systemic

effects resulting from exposure to 2-ME may include central nervous system depression, depression of threshold of neuromuscular stimulation, and liver damage.⁷

Other effects seen in teratogenic and embryo toxic studies include reduction of successful embryo implantation frequency, inhibition of the mitotic process, and inhibition of the gastrulation process.²⁵⁻²⁹ While evidence indicative of potential effects on cell growth was found, extrapolation of these data to humans is difficult.^{20,23}

IV. RECOMMENDED INTERIM EXPOSURE LIMIT

A review of the animal toxicity data for 2-ME revealed that chronic inhalation exposures at a concentration of 6 mg/m^3 produced decreased oxygen consumption, lymphopenia, and neutrophilia. A maximum permissible concentration of 1 mg/m^3 (0.3 ppm) for 2-ME has been recommended for use in industrial establishments in the Soviet Union. Comparison of acute toxicity data for 2-ME with data of structurally similar compounds suggests that 2-ME may be 2.3 times more toxic than butanethiol (TLV = 0.5 ppm), 6.5 times more toxic than ethanethiol, and 6 times more toxic than propanethiol (TLV = 0.5 ppm) via oral administration but may be comparable to propanethiol and less toxic than butanethiol and ethanethiol by the inhalation route of exposure. The TLVs for ethanethiol, methanethiol, and butanethiol were based on discomfort to human volunteers rather than toxicity.

Since 2-ME has many effects similar to those of the thiols discussed and its odor threshold falls in the range of other thiols, by analogy the exposure limit for 2-ME should be comparable to the TLVs for butanethiol and ethanethiol (Table 10). An interim exposure limit (IEL) of 0.5 ppm for a time-weighted average concentration during an 8-hour work shift is recommended. As with other thiols, a nuisance problem due to 2-ME odors and complaints of odor may serve as a primary reason for controlling workplace concentrations.

V. HAZARD MONITORING, WORK PRACTICES, AND CONTROLS

A. Sampling and Analytical Methods

1. Sampling

While various techniques have been used to collect and analyze airborne thiols (mercaptans), no information was found on sampling procedures specific for 2-ME. NIOSH²⁹ has determined that the use of sorbent tubes containing the proper type of absorbent, such as Chromosorb 104 used for butanethiol, should be an efficient and convenient method of collecting thiols. The recommended sampling pump flowrate is between 25 and 70 cc/minute. However, use of Chromosorb 104 has been found unsatisfactory for the determination of ethanethiol. If Chromosorb 104 is to be used for 2-ME, tests should be performed to determine its 2-ME collection efficiency. Any sorbent selected for 2-ME sampling should provide a high collection efficiency with a minimum amount of breakthrough, good storage stability, and a long retention time.

2. Analysis

Only two methods for the analysis of 2-ME have been reported.^{35,36} Paul et al.³⁶ reported on four separate titrimetric methods of determination of mercaptans using chloramine-T and iodine. These methods are fast and quantitative. However, hydrazine, thiocyanate, and thiocarbonyl compounds such as thiourea interfere with these methods, and this limitation should be considered when the methods are used.

Gas chromatographic techniques have been used to detect thiols in the parts per billion (ppb) range. NIOSH³⁴ has validated a gas chromatographic method for 1-butanethiol and noted that it may be used for determining other

n-alkane thiols. No tests have been performed to date on its applicability for 2-ME analysis. Because of structural similarities, this procedure may be applicable for 2-ME analysis.

Fishbein and Zielinski³⁵ reported on the gas chromatographic determination of a number of hydroxyethyl derivatives including 2-ME. A hydrogen flame detector was used along with a column of 4% carbon 20 M terminated with terephthalic acid on 60-80 mesh hexamethyldisilazane (HMDS) pretreated Chromosorb W. A column temperature of 73°C was used with nitrogen carrier flow set at 63 ml/min, hydrogen flow at 45 ml/min, and air flow at 300 ml/min. The hydrogen flame detector temperature was 200°C. A retention time of 3.65 minutes was reported for 2-ME. Based on this review, the methodology used by Fishbein and Zielinski³⁵ is recommended for the analysis of 2-ME.

B. Engineering Controls

Because of its irritating properties 2-ME should be handled in closed systems or under laboratory hoods. Engineering controls installed at facilities which manufacture, use, or store 2-ME should be designed to maintain airborne 2-ME concentrations at or below the recommended exposure limit. Manufacture and use of 2-ME should be performed in properly operated and maintained closed systems which utilize local exhaust ventilation and are vented to flares or scrubber systems to prevent inadvertent discharge of 2-ME and hydrogen sulfide, a production contaminant, into the occupational and community environment. In situations where the use of closed systems is not feasible, local exhaust ventilation systems should be provided at potential emission sources to direct airflow away from the workers' breathing zones. A program of regular inspection and maintenance of ventilation systems and process equipment should be instituted to ensure effective operation of the systems.

Routine inspections should include, as a minimum, measurements of hood face velocity and visual examinations for corrosion of the housing, piping, air movers, and collection or dispersion systems. Manometers should be installed in the system to provide continuous airflow monitoring.

Operator exposure to 2-ME can be further minimized with the use of remote-control-operated instrumentation such as level indicators, pressure gauges, thermometers, and volumetric flow recorders. Tank-car or drum-filling operations should be designed for use of either submerged transfer lines and return vent lines or vent lines connected to flares, with provision for line flush before disconnection.

Additionally, in operations that involve 2-ME production, special precautions are necessary to avoid the release of 2-ME and hydrogen sulfide (a production contaminant) in hazardous concentrations.² Remote sensors to detect 2-ME and hydrogen sulfide should be integrated into the plant warning systems. In the event of emergency evacuation, sufficient egress routes should be available to allow employees to take advantage of the wind direction to minimize exposure from the release site. Wind direction indicators should be installed and positioned so that they are visible from all plant work areas.

Since 2-ME and hydrogen sulfide are corrosive, piping systems and any equipment including the ventilation systems that will come in contact with 2-ME should be constructed of corrosion-resistant materials such as stainless steel. For changes in the process that may affect the ventilation system, equipment should be evaluated to ensure that adequate protection for employees is provided. All exhaust gases should pass through a sulfur recovery system or be exhausted to a scrubber or flare for oxidation.

C. Work Practice Procedures

1. General Procedures

In order to maintain exposure to 2-ME at or below the recommended limit, work practice, and engineering techniques should be oriented toward the use of appropriate procedures for manufacturing, handling, and storing 2-ME. These controls should be primarily concerned with preventing inhalation and protecting skin and eyes from contact with liquids, aerosols, and vapors of 2-ME. The work practices should also include procedures covering emergency response, and selection, use, and care of personal protective clothing and equipment. A regular program of instruction should be established to familiarize all potentially exposed employees with these procedures.

2. Storage and Handling

2-ME reacts violently with dry hypochlorite and is incompatible with oxidizing agents.^{37,38} In the presence of mineral acids, e.g., hydrochloric acid, temperature dependent decomposition occurs more or less rapidly, to produce white polymeric ethylene sulfide of high molecular weight.² Decomposition of this compound results in the release of toxic oxides of sulfur. To prevent this from happening, 2-ME should be stored separately from the above chemicals. Containers of 2-ME should be properly labeled and sealed during transportation and storage. Detailed information on shipping requirements can be found in Department of Transportation Regulation CFR 173.141. Transferral of 2-ME from bulk containers should be done by pumping through a hermetically sealed system of lines that are vented to prevent release of material to both occupational and community environments.

During nonroutine maintenance or repair work, tanks, machines, pumps, valves, and lines should be drained and residual 2-ME removed by steam followed by an oxidizing solution. Purging of containers and lines must also be

done before performing hot work, i.e., external welding or grinding, to minimize releases to the environment. If employees are required to enter a confined space suspected of, or subjected to, contamination by 2-ME, confined-space entry procedures should be followed.

3. Emergency Procedures

In the event of a 2-ME leak or spill, all nonessential personnel should be evacuated from the area. Personnel entering the spill or leak area should utilize neoprene rubber gloves, impervious clothing, and a self-contained breathing apparatus. The area of the leak or spill should be adequately diked to prevent further contamination and all sources of ignition should be removed. For further information, see "Disposal".

2-ME will ignite upon moderate heating. During fire fighting operations, self-contained breathing apparatus and protective clothing should be worn. If a fire occurs, carbon dioxide, water spray, alcohol foam, or dry chemicals may be used for fire extinguishing purposes so that the material can be cooled below its flash point of 74°C (167°F). In the event of a spill, all sources of ignition should be eliminated.^{37,38}

Eyewash fountains and emergency showers should be available in areas where 2-ME splashes, leaks, or spills are possible. If contact with 2-ME occurs, the affected skin areas should be flushed immediately with a copious amount of water. When eye contact has occurred, the affected person should be referred to a medical treatment facility after eyewashing has been completed. If the victim is overcome by fumes, he should be removed to fresh air. In the event that breathing stops, artificial respiration should be administered. If 2-ME is ingested, vomiting should be induced with salt water and the victim referred to a medical treatment facility.^{37,39}

4. Disposal

Prior to disposal, a 2-ME spill should be covered with a weak aqueous calcium hypochlorite solution (up to 15%) and mixed.^{37,38} Addition of dry calcium hypochlorite may cause a violent reaction or flash fire. Sodium hypochlorite, available in 5% concentrations as household bleach, or any equivalent substance which can deactivate 2-ME is also suitable. The solution should be scooped into a large container and neutralized with sulfuric acid or sodium hydroxide as required. The spill site should be washed with a strong soap solution to which some sodium hypochlorite or equivalent has been added. For disposal of waste, 2-ME should be dissolved in waste alcohol or other flammable solvent and burned in an incinerator with an afterburner and scrubber to neutralize the sulfur dioxide.

5. Personal Protective Equipment and Clothing

In areas where 2-ME may be spilled or where prolonged or repeated skin or eye contact may occur, workers should wear impervious clothing, rubber gloves, aprons, boots, and eye protection. All contaminated personal protective equipment should be cleaned thoroughly after each wearing before being reused. Contaminated equipment should be flushed with large amounts of water. For protection against eye irritation, workers should wear a full-face shield or well-fitted chemical safety goggles.

During the performance of nonroutine maintenance or repair, emergency cleanup of spills, or any other such operation where 2-ME exposure levels may be excessive, workers should wear appropriate respiratory protection. The type of respirator required is dependent on the air concentration of 2-ME and should be selected in accordance with the following table.

RESPIRATOR SELECTION GUIDE FOR 2-ME

Concentration	Respirator Type Approved Under Federal Provisions of 30 CFR 11
0.5 ppm	<p>(1) Chemical cartridge respirator with half-mask face piece and organic vapor cartridge.</p> <p>(2) Supplied-air respirator operated in demand mode with half-mask face piece.</p>
>0.5-≤25 ppm	<p>(1) Gas mask with chin-style or front or back-mounted organic vapor canister with full face piece.</p> <p>(2) Supplied-air respirator in demand mode with full face piece.</p> <p>(3) Self-contained breathing apparatus operated in demand mode with full face piece.</p>
>25 ppm	<p>(1) Self-contained breathing apparatus with full face piece operated in pressure-demand mode.</p> <p>(2) Combination supplied-air respirator with full face piece and auxiliary self-contained air supply operated in the pressure-demand mode.</p>
Emergency (entry into area of unknown concentration for purposes such as firefighting)	<p>(1) Self-contained breathing apparatus with full face piece, operated in pressure-demand mode.</p> <p>(2) Combination supplied-air respirator with full face piece and auxiliary self-contained air supply, operated in the pressure-demand mode.</p>

Employees should be fitted for respirator usage and trained in the proper care and use of respirators.

6. Training, Labeling, and Posting

Employees who are occupationally exposed to 2-ME should be informed of the hazards associated with their exposure, the symptoms associated with such an exposure, the appropriate emergency procedures, and proper procedures for the safe handling and use of 2-ME. Warning signs should be posted informing employees of the health and safety hazards and the appropriate precautionary measures. These warning signs should be printed in English and the predominant language of any non-English reading worker. The information on warning signs should be arranged as follows:

2-MERCAPTOETHANOL

HARMFUL IF INHALED

AVOID SKIN CONTACT

MAY CAUSE SKIN IRRITATION

Use with adequate ventilation. Avoid inhaling vapor or mist. Do not get in eyes, on skin, or on clothing. Keep containers closed when not in use.

Containers of 2-ME should be marked with labels that provide the name of the product and health hazard information as well as first-aid and fire fighting instructions. The information should be arranged as follows:

2-MERCAPTOETHANOL

MAY BE HARMFUL IF ABSORBED THROUGH SKIN,

INHALED, OR INGESTED

MAY CAUSE SKIN AND EYE IRRITATION

KEEP CONTAINER CLOSED WHEN NOT IN USE

Do not get on skin, in eyes or mouth, or on clothing.

Avoid inhaling vapor.

Use only with adequate ventilation.

Keep containers closed when not in use.

Wash hands and face thoroughly before eating, drinking, smoking, or using toilet.

First Aid: In case of contact with eyes or skin, immediately flush eyes with a copious amount of water for 15 minutes; wash skin with soap and water. A physician should be contacted promptly. If victim is overcome, remove to fresh air. If breathing stops or is impaired, give artificial respiration and seek medical assistance. If substance is swallowed, induce vomiting and seek medical assistance.

Fire Fighting: Use alcohol foam, water spray, carbon dioxide, or chemicals.

D. Medical Surveillance Procedures

A medical surveillance program should be established that will provide preplacement and periodic medical examinations to all workers exposed to 2-ME. The preplacement examination should include comprehensive medical and work histories with emphasis on symptoms and signs of disorders of the central nervous system, autonomic nervous system, cardiovascular system, skin, eyes and liver. An evaluation of the worker's ability to use respirators should be made as well. Periodic examinations should be made available to workers exposed to 2-ME. Pertinent medical and environmental exposure records should be retained for at least 30 years after employment ends.

VI. RESEARCH NEEDS

A. Animal Studies

Acute and chronic inhalation studies in several animal species are needed to determine the effect of exposure to 2-ME. Studies of different species are required to determine the carcinogenic, mutagenic, and teratogenic potential of 2-ME. Research is also needed in evaluating the rate and character of 2-ME metabolism. Information obtained from metabolic studies may result in the identification of parameters useful for biological monitoring of exposures to 2-ME.

B. Sampling and Analytical Studies

There is a need for the development of continuous direct-reading area monitors and personal samplers for 2-ME. Research is needed to develop a sampling device for 2-ME using absorbents with a high collection efficiency, a minimum amount of breakthrough, good storage stability, and long retention time.

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TABLE 1

Summary of 2-Mercaptoethanol PropertiesFormula CAS No. 60-24-2Synonyms

1-Ethanol-2-thiol	Monothioethyleneglycol
2-Hydroxy-1 ethanethiol	2-Thioethanol
2-Hydroxyethyl mercaptan	Thioglycol
2-ME	Thiomonoglycol
Mercaptoethanol	

Physical Description

White mobile liquid with a strong unpleasant odor.

Physical and Chemical Properties

Mol wt = 78.13; bp = 157.1°C, flash pt. = 170°F (C.O.C.); d = 1.1168
at 20°/20°C; vap. press. = 1.0 mm Hg at 20°C; vap d. = 2.69,

Hazard Analysis

Fire Hazard: Moderate, when exposed to heat or flame.

Disaster Hazard: Dangerous when heated to decomposition. It emits highly toxic fumes of oxides of sulfur; can react with oxidizing materials.

Incompatibilities: Strong oxidizing agents.

Table 2

Vapor-pressure Characteristics of 2-Mercaptoethanol*

<u>Temperature</u> <u>°C</u>	<u>Pressure</u> <u>(mm Hg)</u>	<u>Estimated</u> <u>Saturated Vapor</u> <u>Concentration (ppm)</u>
20	1	1.3×10^3
53.5	10	1.3×10^4
68	20	2.6×10^4
77	37	4.9×10^4
78.5	40	5.3×10^4
92	78	1.0×10^5
98	100	1.3×10^5
157	748	9.8×10^5

* Adapted from Ref. 40.

TABLE 3

NAME, SYNONYMS AND FORMULA FOR STRUCTURALLY SIMILAR COMPOUNDS

<u>Name</u>	<u>Synonyms</u>	<u>Structural Formula</u>
2-Mercaptoethanol	1-ethanol-2-thiol. 2-hydroxy-1-ethanethiol. 2-hydroxyethyl mercaptan. 2-mercaptoethanol, mono- thioethyleneglycol, 2- thioethanol, thioglycol, thiomonoglycol, 2-ME	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{S}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array} $
Methanethiol	mercaptomethane, methyl- mercaptan, methylsulf- hydrate, thiomethylalcohol	$ \begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{SH} \\ \\ \text{H} \end{array} $
Ethanethiol	ethylmercaptan, ethyl- sulfhydrate, ethylthio- alcohol, mercaptoethane, thioethanol, thioethylalcohol	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{SH} \\ \quad \\ \text{H} \quad \text{H} \end{array} $
1-Propanethiol	3-mercaptopropane, propane- 1-thiol, n-propylmercaptan	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{SH} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array} $
1-Butanethiol	1-butylmercaptan, n-butyl- thiolalcohol, 1-mercapto- butane, thiolbutylalcohol	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{SH} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array} $
Thioglycerol	1-thioglycerol, 1-mercapto- glycerol, 1-mercapto-2,3- propanediol, 3-mercapto-1,- 2-propanediol, monothio- glycerol, alpha-mono-thio- glycerol, thioglycerin, alpha-thioglycerol	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \\ \text{H} \quad \text{O} \quad \text{H} \\ \quad \quad \\ \quad \quad \text{H} \end{array} $
2,3-Dimercaprol	british antilewisite (BAL) dicapitol, dimercaprol, dimercaprolpropanol, di- mercaptol, 2,3-dimercapto- propanol, 2,3-dimercaptol- 1-propanol, dithioglycerol, 1,2-dithioglycerol, 2,3- dithiopropanol	$ \begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \\ \text{H} \quad \text{S} \quad \text{H} \\ \quad \quad \\ \quad \quad \text{H} \end{array} $

TABLE 4

PHYSICAL AND CHEMICAL PROPERTIES OF STRUCTURALLY SIMILAR COMPOUNDS*

Compound	Formula Weight	Boiling Point (°C)	Melting Point (°C)	Specific Gravity (20°/4°C)	Vapor Pressure @ Temp. (mm Hg)	Temp. (°C)	Flash Point (°F)	PEL ppm	TLV ppm	IDLH** ppm
Butanethiol	90.19	98.46°	-115.67°	0.8337	98.2	37.8°	35°	10	0.5	2500
Ethanethiol	62.13	35°	-144.4°	0.8391	442	20°	55°	10	0.5	2500
Methanethiol	48.11	6.2°	-123°	0.8665	2.259	37.8°	<0°	10	0.5	400
2-Mercaptoethanol	78.13	157.1°	--	1.1143	1	20°	170°			

*Adopted from Ref. 34.

**Immediately dangerous to life and health.

TABLE 5

PHYSICAL AND CHEMICAL PROPERTIES OF STRUCTURALLY SIMILAR COMPOUNDS

<u>Compound</u>	<u>Formula Weight</u>	<u>Boiling Point</u>		<u>Melting Point</u>	<u>Specific Gravity</u> <u>20°/4°C</u>	<u>Vapor Pressure</u>		<u>Flash Point</u>
		<u>(°C)</u>	<u>(mm Hg)</u>	<u>(°C)</u>		<u>(mm Hg)</u>	<u>(°C)</u>	<u>(°C)</u>
Methanethiol	48.11	6.2°	--	-123°	.8665	2.259	37.8°	<0°
Ethanethiol	62.13	35°	760	-144.4°	.8391	442.	20°	55°
1-Propanethiol	76.17	67.68°	760	-113.3°	.8411	155.	25°	<0
Mercaptoethanol	78.13	157.1°	742	--	1.1143	1.	20°	170°
1-Butanethiol	90.19	98.46°	760	-155.67°	.8337	98.2	37.8°	35°
Thioglycerol	118.	118°	5	--	1.295	--	--	--
2,3-Dimercaprol	124.23	--	--	77.	1.2385	--	--	--

TABLE 6
COMPARISON OF TOXICITY DATA*

Inhalation Exposures

<u>Compound</u>	<u>Species</u>	<u>LD₅₀</u>
Butanethiol	rat	4020 ppm/4H ^a
Ethanethiol	rat	4420 ppm/4H ^a
Methanethiol	rat	675 ppm ^b
2-Mercaptoethanol	mus	4130 ppm/2H ^c
Butanethiol	mus	2500 ppm/4H ^a
Ethanethiol	mus	2770 ppm/4H ^a
Propanethiol	mus	4010 ppm/4H ^a

Oral Exposures

<u>Compound</u>	<u>Species</u>	<u>LD₅₀</u>
2-Mercaptoethanol	rat	300 mg/kg ^d
Butanethiol	rat	1500 mg/kg ^a
Ethanethiol	rat	682 mg/kg ^e
Ethanethiol	rat	1960 mg/kg ^e
2-Mercaptoethanol	mus	345 mg/kg ^f

^aFairchild, E.J., H.E. Stokinger.⁴²

^bPersonal Communication.⁴³

^cFrom Pugaeva, et al.⁷

^dFrom Smyth, et al.⁹

^eJ.V. Marhold, Sbornik Vysledku Toxikologickeho Vysetreni Latek A Pripravku, Institut Pro Vychovu Vedoucich Pracovniku Chemickeho Prumyslu Praha, Czechoslovakia, 1972.

^fFrom White, et al.⁸

*Adapted from 1978 Registry of Toxic Effects of Chemical Substances.⁴¹

TABLE 7
COMPARISON OF ACUTE TOXICITY DATA
FOR STRUCTURALLY SIMILAR COMPOUNDS*

Oral Exposures

<u>Compound</u>	<u>Species</u>	<u>LD₅₀(mg/kg)</u>	<u>Time Observed</u>	<u>Moles</u>
2-Mercaptoethanol	Rat	300	14	3.84
Butanethiol	Rat	1500	15d	16.63
Ethanethiol	Rat	1960	-	31.55
Ethanethiol	Rat	682	15d	10.98
Propanethiol	Rat	1790	15d	23.50

*Adapted from Ref. 41.

TABLE 8

COMPARISON OF ACUTE TOXICITY DATA
FOR STRUCTURALLY SIMILAR COMPOUNDS*

<u>Intraperitoneal Exposures</u>			
<u>Compound</u>	<u>Species</u>	<u>LD₅₀(mg/kg)</u>	<u>Moles</u>
2-Mercaptoethanol	Mus	200	2.56
2-Mercaptoethanol	Mus	322	4.12
Thioglycerol	Mus	400	3.70
2,3-Dimercaptopropanol	Mus	25	.20
Ethanethiol	Rat	450	7.20
Propanethiol	Rat	515	7.76
Butanethiol	Rat	390	4.32

*Adapted from Ref. 41.

TABLE 9

COMPARISON OF ACUTE TOXICITY DATA
FOR STRUCTURALLY SIMILAR COMPOUNDS*

Inhalation Exposures

<u>Compound</u>	<u>Species</u>	<u>LD₅₀(ppm)</u>	<u>Time Observed</u>
Methanethiol	Rat	675	15 days
Ethanethiol	Rat	4420	48 hours
Propanethiol	Rat	7300	15 days
Butanethiol	Rat	4020	15 days
2-Mercaptoethanol	Mus	4130	
Ethanethiol	Mus	2770	48 hours
Propanethiol	Mus	4010	15 days
Butanethiol	Mus	2500	15 days

*Adapted from Ref. 41 and 34.

TABLE 11

SUMMARY OF ACUTE TOXICITY OF 2-MERCAPTOETHANOL

<u>Route</u>	<u>Species</u>	<u>Toxicity Level</u>		<u>Reference</u>
Oral	rat	LD ₅₀	300 mg/kg	9
Skin	gpg	LD ₅₀	0.3 ml/kg	9
Oral	mus	LD ₅₀	345 mg/kg	8
ip	mus	LD ₅₀	322 mg/kg	8
ig	mus	LD ₅₀	190 mg/kg	7
ig	rat	LD ₅₀	224 mg/kg	7
inh	mus	LC ₅₀	13.2 mg/l	7

TABLE 10

NAME, STRUCTURAL, FORMULA, and RECOMMENDED EXPOSURE
LIMITS FOR STRUCTURALLY SIMILAR COMPOUNDS

Name	Recommended Exposure Limit				
	OSHA		ACGIH		NIOSH
	PEL (ppm)	(mg/m ³)	TLV (ppm)	(mg/m ³)	(mg/m ³)
2-Mercaptoethanol					
Methanethiol	10	2.0	0.5	1.0	1.0
Ethanethiol	10	25	0.5	1.0	1.3
1-Propanethiol				0.5	1.6
1-Butanethiol	10	35	0.5	1.0	1.8
Thioglycerol	-	-	-	-	-
2,3-Dimercaprol	-	-	-	-	-

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