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ABSTRACT: This information profile on*methacrylic acid (79414) is part of a group of 46 such profiles that provide information about chemicals or industrial processes considered to be potential occupational hazards. Each profile contains summary data on known and suspected health effects, the extent of worker exposure and the industrial importance of either a single chemical, class of chemicals, or a particular industrial process. The report was developed for use by occupational safety and health professionals in industry, and labor and other areas, to provide them with a synopsis of information on each subject and to identify potential hazards in their workplaces.



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# INFORMATION PROFILES ON POTENTIAL OCCUPATIONAL HAZARDS

## VOLUME II. CHEMICAL CLASSES

Center for Chemical Hazard Assessment
Syracuse Research Corporation
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Final Report
Contract No. 210-78-0019

December 1979

Prepared for:
National Institute for Occupational Safety and Health
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## INTRODUCTION

An information profile is a working paper used by the National Institute for Occupational Safety and Health (NIOSH) to assist in establishing Institute priorities. It is an initial step in determining the need to develop comprehensive documents or to initiate research. Each profile summarizes data on known and suspected health effects, the extent of worker exposure, physical and chemical properties, and the industrial importance of individual chemicals and classes of chemicals. The profile may also be used by industry, labor, and the occupational health community as a synopsis of information on each subject and to identify possible health hazards associated with their workplaces.

Although detailed literature searches are conducted using computerized and manual searching techniques to identify pertinent and recent information, not all the literature obtained is incorporated in the report due to the summary nature of the profiles. Further, literature published after 1978 may not be included in these profiles because it was generally unavailable at the time the search was completed.

# METHACRYLIC ACID AND ESTERS


## SUMMARY

The main use of methacrylic acid is in the preparation, via esterfication, of methacrylates higher than the methyl ester; it is also used in the preparation of carboxylated and emulsion polymers. Methyl methacrylate and higher methacrylate esters are used primarily in the manufacture of acrylic polymers for surface coatings (latex, lacquer, enamels) and resins. Production of methyacrylic acid in 1975 has been estimated to be approximately 80 million pounds; the production of methyl methacrylate was 745 million pounds in 1977, and the total production of the six major commercial higher methacrylate esters is probably in excess of 100 million pounds. Approximately 229,000 workers are exposed occupationally to methacrylic acid and its esters each year.

In humans, a concentration of 200 ppm methyl methacrylate is irritating to the respiratory system, but skin irritation or sensitization has not occurred following cutaneous applications. Methyl-, ethyl-, and n-butyl-methacrylate cause temporary irritation of the skin and eyes of rabbits, and sensitization has been recorded in guinea pigs. These three chemicals have also been found to interfere with respiration and reflex activity of laboratory animals administered oral, subcutaneous, or inhaled doses, and abnormalities have been observed in the lungs, livers, kidneys, thymus glands, and bladders of treated animals. Embryo-fetal toxicity and teratogenic effects have been produced in rats administered methyl-, n-butyl-, isobutyl-, and ethyl methacrylate during gestation.

1. Synonyms

2. Chemical Abstracts Service (CAS) Number

3. Registry of Toxic Effects of Chemical Substances (RTECS) Number

4. Molecular Formula

5. Chemical Structure

6. Physical and Chemical Properties

The above information for methacrylic acid and its esters is listed in Table 1.

7. Producer and User Data

Methacrylic Acid

Production of methacrylic acid in 1975 has been estimated to be roughly 80 million pounds (Blackford, 1976). Growth rates for methacrylic acid have been in the neighborhood of 7 percent per year (Blackford, 1975).

The main use of methacrylic acid is in the preparation, via esterification, of methacrylates higher than the methyl. It is also used in the preparation of carboxylated polymers and as a minor monomer constituent of emulsion polymers for adhesives, paints, polishes, and textiles (Blackford, 1976).

Methacrylic acid is manufactured by DuPont in Belle, W. Va. and by Rohm and Haas in Bristol, Pa. and in Deer Park, Tex. (SRI, 1978).

Methacrylic acid production is based upon the acetone cyanohydrin process (Blackford, 1976). In this process, acetone and hydrogen cyanide are reacted to produce acetone cyanohydrin, which is treated with concentrated sulfuric acid to form methacrylamide sulfate. Without being isolated, the methacrylamide sulfate is reacted directly with water to form crude methacrylic acid. Purification is accomplished via distillation. Substitution of the water with methanol during the methacrylamide sulfate reaction yields methyl methacrylate.

Methyl Methacrylate

Methyl methacrylate is by far the most commercially important ester of methacrylic acid. Production of methyl methacrylate was 745 million pounds in 1977 (USITC, 1977). Industry capacity to produce methyl methacrylate is 1.1 billion pounds (SRI, 1978). Growth of methyl methacrylate is expected to be 8-9% per year (Chem. Prof., 1976).

Methyl methacrylate has the following use patterns (Chem. Prof., 1976; Blackford, 1976):

| | |
|---|---|
| Acrylic sheet production | 45% |
| Surface coatings (latex, lacquer, enamels) | 23 |
| Moldings and extrusion powders | 21 |
| Miscellaneous (export, polymers, polyesters, transesterfications, fibers) | 11 |

The manufacturing process for methyl methacrylate is given under methacrylic acid.

Higher Methacrylate Esters

The major commercial, higher methacrylate esters are listed below (Blackford, 1976):

| | |
|---|---|
| n-butyl- | isobutyl- |
| ethyl- | lauryl- |
| 2-ethylhexyl- | stearyl- |

Total production of the above six methacrylate esters is probably in excess of 100 million pounds (SRC estimate). An individual breakdown is not available. Growth of the higher methacrylate esters has been approximately 7 percent per year (Blackford, 1975).

n-Butyl, ethyl, 2-ethylhexyl, and isobutyl methacrylates are used chiefly in the manufacture of acrylic polymers for surface coatings, resins, and especially as a flexibility-imparting comonomer with methyl methacrylate in acrylic lacquers. Use in acrylic emulsion polymers is also a significant market for these esters. Lauryl and stearyl methacrylates are used primarily in polymeric additives for automobile lubricating oils and distillate fuels (Blackford, 1976).

The above higher methacrylates are produced by Dupont and Rohm & Haas (Blackford, 1976).

The higher methacrylates are manufactured primarily by the direct esterification of methacrylic acid with the corresponding alcohol. They are also manufactured by the transesterification of the lower methacrylates; the reaction may be represented as follows (Blackford, 1976):

$$CH_2{=}\underset{\displaystyle CH_3}{\overset{|}{C}}COOCH_3 + ROH \xrightarrow{H^+} CH_2{=}\underset{\displaystyle CH_3}{\overset{|}{C}}COOR + CH_3OH$$

(methyl methacrylate)

About 10 million pounds per year of methyl methacrylate are used for transesterifications (Blackford, 1976).

Table 1. Methacrylic Acid and Its Esters

| | Methacrylic acid | Methyl methacrylate | Ethyl methacrylate | n-Butyl methacrylate |
|---|---|---|---|---|
| Synonyms | 2-Propenoic acid, 2-methyl | 2-Propenoic acid, 2-methyl-, methyl ester | 2-Propenoic acid, 2-methyl-, ethyl ester | 2-Propenoic acid, 2-methyl-, butyl ester |
| CAS Number | 79-41-4 | 80-62-6 | 97-63-2 | 97-88-1 |
| RTECS Number | OZ29750 | OZ50750 | OZ45500 | OZ36750 |
| Molecular Formula | $C_4H_6O_2$ | $C_5H_8O_2$ | $C_6H_{10}O_2$ | $C_8H_{14}O_2$ |
| Chemical Structure | $CH_2:C(CH_3)CO_2H$ | $CH_2:C(CH_3)CO_2CH_3$ | $CH_2:C(CH_3)CO_2C_2H_5$ | $CH_2:C(CH_3)CO_2(CH_2)_3CH_3$ |
| Physical and Chemical Properties | | | | |
| Molecular Weight | 86.10 | 100.13 | 114.16 | 142.22 |
| Physical State | Liquid | Liquid | Liquid | Liquid |
| Boiling Point, °C | 163 at 757 mm | 100 | 118 | 163 |
| Melting Point, °C | 16 | -48 | | |
| Vapor Pressure | 1 mm at 25.5°C | 40 mm at 25.5°C | | |
| Evaporation Rate | | | | |
| Solubility | Sol. in warm $H_2O$ | Slightly sol. in $H_2O$ | Slightly sol. in $H_2O$ | Insol. in $H_2O$ |
| Specific Gravity | 1.0153 (20/4°C) | 0.943(20/4°C) | 0.907(20/4°C) | 0.895(20/4°C) |
| Stability | | | | |

Table 1. Methacrylic Acid and Its Esters (Cont'd)

| | Isobutyl methacrylate | 2-Ethylhexyl methacrylate | Lauryl methacrylate |
|---|---|---|---|
| Synonyms | 2-Propenoic acid, 2-methyl-, 2-methylpropyl ester | 2-Propenoic acid, 2-methyl-, 2-ethylhexyl ester | 2-propenoic acid 2-methyl-, dodecyl ester |
| CAS Number | 97-86-9 | 688-84-6 | 142-90-5 |
| RTECS Number | OZ49000 | OZ46300 | OZ43000 |
| Molecular Formula | $C_8H_{14}O_2$ | $C_{12}H_{22}O_2$ | $C_{16}H_{30}O_2$ |
| Chemical Structure | $CH_2{:}C(CH_3)CO_2CH_2CH(CH_3)_2$ | $CH_2{:}C(CH_3)CO_2$ - $CH_2CH(CH_2)_3CH_3$ $CH_2CH_3$ | $CH_2{:}C(CH_3)CO_2C_{12}H_{25}$ |
| Physical and Chemical Properties | | | |
| Molecular Weight | 142.22 | 198.34 | 254.46 |
| Physical State | | | |
| Boiling Point, °C | 155 | | 272-343 |
| Melting Point, °C | | | -22 |
| Vapor Pressure | | | |
| Evaporation Rate | | | |
| Solubility | Insol. in $H_2O$ | | |
| Specific Gravity | 0.889(16/16°C) | | 0.868(25/5°C) |
| Stability | | | |

Table 1. Methacrylic Acid and Its Esters (Cont'd)

| | Stearyl Methacrylate | 2-Dimethylamino-ethyl methacrylate | t-Butylaminoethyl methacrylate |
|---|---|---|---|
| Synonyms | 2-Propenoic acid, 2-methyl-, octadecyl ester | 2-Propenoic acid, 2-methyl-, 2-(dimethylaminoethyl) ester | 2-Propenoic acid, 2-methyl-, 2-[(1,1-dimethylethyl)amino]ethyl ester |
| CAS | 32360-05-7 | 2867-47-2 | 3775-90-4 |
| RTECS Number | | OZ42000 | OZ35000 |
| Molecular Formula | $C_{22}H_{42}O_2$ | $C_8H_{15}O_2N$ | $C_{10}H_{19}O_2N$ |
| Chemical Structure | $CH_2:C(CH_3)CO_2C_{18}H_{37}$ | $CH_2:C(CH_3)CO_2CH_2CH_2N(CH_3)_2$ | $CH_2:C(CH_3)CO_2CH_2CH_2NH(C_4H_9)$ |
| Physical and Chemical Properties | | | |
| Molecular Weight | | 157.24 | 185.30 |
| Physical State | | | |
| Boiling Point, °C | 310-370 | 68.5 (diester) | 93 (diester) |
| Melting Point, °C | 15 | | |
| Vapor Pressure | | | |
| Evaporation Rate | | | |
| Solubility | | | |
| Specific Gravity | 0.864(25/5°C) | 0.933(25/5°C) | 0.914(25/5°C) |
| Stability | | | |

8. Biological Effects of Exposure

a) Acute Effects

A summary of acute effects is presented in Table 2.

Deichmann (1941) studied the toxicity of methyl, ethyl, and n-butyl methacrylate on various laboratory animals. Oral administration and subcutaneous injection of a lethal dose of one of the preceding chemicals produced the following symptoms in rats and rabbits: increased respiration (with lacrimation in rats) in 2-5 minutes, followed by motor weakness and decreased respiration in 15-40 minutes. Breathing became shallow and irregular, defecation and urination increased, reflex activity ceased, coma and death followed. Inhalation of 2.9-24 ppm for 8 hours produced similar symptoms as well as irritation of the mucous membranes. Deichmann (1941) noted a variation in susceptibility of rats to methyl methacrylate based on the age of the animal. Adults and 4 week old rats died within 2-3 hours when exposed to 26 mg/l while 4 day old pups died within 4-5 hours.

Neither methyl, ethyl, nor n-butyl methacrylate caused any alterations in blood chemistry values or in hemoglobin levels. Pathological examination found the lungs, trachea, and bronchi congested, edematous, and spotted with areas of hemorrhage and emphysema; the thymus gland was swollen and congested and spotted with petechial hemorrhages; auricles were dilated and filled with dark clotted blood; and the bladder was distended and often contained blood (Deichmann, 1941).

When 0.03 or 0.04 ml/kg of methyl, ethyl, or n-butyl methacrylate were administered intravenously to rabbits anesthesized with sodium barbitol, a prompt and sudden fall in arterial blood pressure was recorded, with recovery in 3-4 minutes (Deichmann, 1941). Respiration was stimulated immediately and continued at an increased rate for 20-30 minutes. When one or two additional sublethal doses were given, blood pressure again decreased and then returned to normal. Respiration continued to decrease and finally ceased. It was noted that the heart continued to beat for some time after respiratory arrest. Elevated blood porphyrins were found in rabbits given single injections of 2 ml/kg/week for three weeks.

Data accumulated on methyl methacrylate by Spealman (1945) agreed with the results presented above. Table 3 summarizes the acute inhalation studies.

Table 2. Acute Toxicity

| Species | Route | Dose | Result | Reference |
|---|---|---|---|---|
| Methacrylic acid | | | | |
| mouse | ipr | 48 mg/kg | $LD_{50}$ | NIOSH, 1977 |
| Methyl methacrylate | | | | |
| rat | oral | 8000 mg/kg | $LD_{LO}$ | NIOSH, 1977 |
| rat | ihl | 3750 ppm | $LC_{50}$ | NIOSH, 1977 |
| rat | ipr | 1328 mg/kg | $LD_{50}$ | Singh et al., 1972 |
| rat | scu | 7500 mg/kg | $LD_{50}$ | Spealman et al., 1945 |
| mouse | ipr | 1000 mg/kg | $LD_{50}$ | Spealman et al., 1945 |
| mouse | scu | 6300 mg/kg | $LD_{LO}$ | Spealman et al., 1945 |
| dog | oral | 5000 mg/kg | $LD_{50}$ | Spealman et al., 1945 |
| dog | scu | 4500 mg/kg | $LD_{50}$ | Spealman et al., 1945 |
| rabbit | oral | 6550 mg/kg | $LD_{LO}$ | Diechmann, W., 1941 |
| rabbit | ihl | 17500 mg/m$^3$/4 hrs. | $LC_{LO}$ | Deichmann, W., 1941 |
| guinea pig | oral | 6300 mg/kg | $LD_{50}$ | Spealman et al., 1945 |
| guinea pig | ihl | 19000 mg/m$^3$/5 hrs. | $LC_{LO}$ | Deichmann, W., 1941 |
| guinea pig | ipr | 2000 mg/kg | $LD_{50}$ | Spealman et al., 1945 |
| guinea pig | scu | 6300 mg/kg | $LD_{50}$ | Spealman et al., 1945 |
| Ethyl methacrylate | | | | |
| rat | oral | 14800 mg/kg | $LD_{50}$ | Deichmann, W., 1941 |
| rat | ihl | 15000 mg/m$^3$/3 hrs. | $LC_{LO}$ | Deichmann, W., 1941 |
| rat | ipr | 1223 mg/kg | $LD_{50}$ | Singh et al., 1972 |
| rat | scu | 25 gm/kg | $LD_{LO}$ | Deichmann, W., 1941 |
| mouse | ipr | 1369 mg/kg | $LD_{50}$ | NIOSH, 1977 |
| rabbit | oral | 3630 mg/kg | $LD_{LO}$ | Deichmann, W., 1941 |
| Butyl methacrylate | | | | |
| rat | oral | 20 gm/kg | $LD_{LO}$ | Deichmann, W., 1941 |
| rat | ipr | 2304 mg/kg | $LD_{50}$ | Singh et al., 1972 |
| mouse | ipr | 256 mg/kg | $LD_{LO}$ | Singh et al., 1972 |
| rabbit | oral | 6270 mg/kg | $LD_{LO}$ | Deichmann, W., 1941 |
| Isobutyl methacrylate | | | | |
| rat | oral | 6400 mg/kg | $LD_{LO}$ | NIOSH, 1977 |
| rat | ipr | 1400 mg/kg | $LD_{50}$ | Singh et al., 1972 |
| mouse | ipr | 1340 mg/kg | $LD_{50}$ | NIOSH, 1977 |
| 2-Ethylhexyl methacrylate | | | | |
| mouse | ipr | 2614 mg/kg | $LD_{50}$ | NIOSH, 1977 |
| Dodecyl methacrylate | | | | |
| mouse | ipr | 25 mg/kg | $LD_{50}$ | NIOSH, 1977 |
| Dimethylaminoethyl methacrylate | | | | |
| mouse | ipr | 104 mg/kg | $LD_{50}$ | Lawrence et al., 1972 |
| tert-Butylaminoethyl ester | | | | |
| mouse | ipr | 190 mg/kg | $LD_{50}$ | NIOSH, 1977 |

Table 3. Acute Inhalation Data

| Species | Dose | Results |
|---|---|---|
| mice | 47.7 mg/ℓ/5 hours | 9/15 died. Liver degeneration, hepatitis, and focal necrosis |
| | 61.8 mg/ℓ/3 hours | 15/15 died. Liver degeneration, hepatitis, and focal necrosis |
| guinea pigs | 72.1 mg/ℓ/4-1/4 hours | 6/6 died. Liver degeneration |
| dogs | 41.2 mg/ℓ/3 hours | 2/2 died. Liver degeneration and tubular degeneration of kidneys |
| dogs | 72.1 mg/ℓ/1-1/2 hours | 2/2 died. Liver degeneration and tubular degeneration of kidneys |

Cutaneous application of 10 ml/kg of methyl, ethyl, and n-butyl methacrylate to rabbits clipped of their fur produced temporary local irritation and malaise (Deichmann, 1941). The animals recovered within one hour. Fleeting irritation was also noted by Spealman (1945) when 20 ml/kg of methyl methacrylate was applied to the skin of rabbits. At a higher dose, 40 ml/kg, depression of the central nervous system was observed.

Three drops of methyl methacrylate placed in the eyes of rabbits caused edema and inflammation of the conjunctiva (Spealman, 1945). At the end of 72 hours, the eyes had returned to normal.

In a study of contact sensitization potentials of methyl, ethyl, and n-butyl methacrylates, Chung and coworkers (1976) found that guinea pigs did not suffer any immediate skin reactions when any one of the three chemicals was applied topically in ethanol; however, strong positive reactions were found in animals subsequently challenged with methacrylates in olive oil regardless of the route of immunization, immunogen dose, or type of methacrylate. Sensitization to all three esters occurred when administered in ethanol or olive oil by the topical route, or in saline by the intradermal route. Once sensitized, animals responded to methacrylates other than the inducer.

Kessler and coworkers (1977) reported the accidental poisoning of a rhesus monkey exposed to methyl methacrylate vapors for 22 hours. The animal was found in a comatose condition and died several hours later. Autopsy findings included: mild pulmonary edema, emphysema and atelectasis of the lungs; the liver was mottled with centrilobular necrosis; and a clear yellow fluid had collected in the thoracic cavity. An analysis of blood values showed normal erythrocyte and leukocyte counts as well as normal packed cell volume and hemoglobin content. The serum glutamic oxaloacetic transaminase, serum phosphohexose isomerase, blood urea nitrogen, and serum sodium values were all elevated.

The effects of graded infusions of monomethylmethacrylate in dogs were studied by Modig and coworkers (1975). Four dogs received 4-5 successively larger intravenous infusions of 0.005-2 ml each. It was found that monomethylmethacrylate did not affect the clotting mechanism, did not cause trapping of platelets and fibrin in the lungs, did not generate fat emboli, and did not depress the arterial oxygen tension or blood pressure.

Methyl methacrylate vapor was found to cause a direct inhibitory effect upon gastrointestinal smooth muscle that also involves the cardiopulmonary system (Tansy et al., 1977; Tansy et al., 1975). Anesthetized dogs exposed to a concentration of 2000 ppm experienced depression of tonus and contractile activity of the antrum and proximal small bowel. Decreased pulse pressure and probably a reflex tachycardia may have been caused by two possible mechanisms: an increase in arterial compliance, and a decrease in myocardial contractility. Neither bilateral vagotomy, spinal transection, splanchnectomy, nor tetraethylammonium chloride blocked the effects of methyl methacrylate.

b ) Subchronic Effects

Subchronic inhalation experiments were conducted with methyl methacrylate by Spealman (1945). The results are summarized in Table 4. Treated dogs exhibited symptoms of depression preceded by ataxia, excess salivation, vomiting, and irritation.

Table 4. Subchronic Inhalation Study

| Species | Dose | | Results |
|---|---|---|---|
| mice | 41.2mg/ℓ | 1/2hr/day/15 days | 1/20 Died. No significant effects. |
| | 41.2mg/ℓ | 1-1/2hr/day/15 days | 2/20 Died. No significant effects. |
| guinea pigs | 39.3mg/ℓ | 3hr/day/15 days | 0/6 Died. No significant effects. |
| | 65.5mg/ℓ | 3hr/day/3 days | 6/6 Died. Liver degeneration. |
| dogs | 41.2mg/ℓ | 1/2hr/day/15 days | 1/2 Died. No significant effects. |
| | 46.8mg/ℓ | 1/2hr/day/15 days | 1/2 Died. Liver degeneration and tubular degeneration of the kidneys. |
| | 46.8mg/ℓ | 1-1/2hr/day/8 days | 2/2 died. Liver degeneration and tubular degeneration of the kidneys. |

c) Chronic Effects

i. Carcinogenicity

Forty male and female mice received implants consisting of 0.075 gm of methyl methacrylate in a gelatin capsule (Spealman, 1945). The mice were observed for nine months, during which time no tumors, growths, or other abnormalities were discovered.

ii. Mutagenicity

No data were encountered.

iii. Teratogenicity

The embryonic fetal toxicity and teratogenic effects of several methacrylate esters were studied by Singh and coworkers (1972). Female Sprague-Dawley rats were administered intraperitoneal injections on days 5, 10, and 15 of gestation at three dose levels equivalent to 1/10, 1/5, and 1/3 of the $LD_{50}$ of each chemical. The results are summarized in Table 5. When compared to the pooled volume control (untreated, distilled water, normal saline, and cottonseed oil), significant effects included increased resorptions at all three doses of ethyl methacrylate, the high doses of n-butyl and isobutyl methacrylate, and the two highest doses of isodecyl methacrylate. The occurrence of gross abnormalities increased in all groups except those receiving the low dose of methyl methacrylate and the two lowest doses of n-butyl methacrylate. Fetal weight decreased significantly in all treated groups when compared to the untreated controls.

iv. Other Effects

No data were encountered.

d) Human Effects

Human toxicity data were encountered for methyl methacrylate only. Fifty medical students were tested for primary irritation from methyl methacrylate by applying a soaked cotton pad to the skin for 48 hours (Spealman, 1945). Fifteen students reacted to one batch of methyl methacrylate while six reacted to another. The reactions occurred within a few hours to four days and consisted of erythematous, itching areas. No reactions occurred when the students were tested for sensitization ten days later. The polymeric form of methyl methacrylate did not cause irritation or sensitization.

An isotope dilution technique was used by Corkill and coworkers (1976) to determine the rate of disappearance of methyl methacrylate in human blood in vitro. The rate of disappearance showed a first order dependence on methacrylate concentration. The calculated half-life was 20-40 minutes irrespective of the sex or age of the blood donor. More than 40% of the initial methyl methacrylate was converted to methacrylic acid in 90 minutes; thus, methacrylic acid is felt to be the major, if not the sole, product of the initial step in metabolism.

Irritation and tolerance of workers exposed to methyl methacrylate were studied by the Connecticut Department of Public Health (ACGIH, 1974). Their findings are presented below:

| Concentration | Result |
|---|---|
| 100 ppm | Tolerated for 8 hours with no complaints |
| 170-250 ppm | Irritation |
| 200 ppm | Tolerable |
| 2300 ppm | Unbearable |

Table 5. Embyronic-Fetal Toxicity of a Group of Methacrylate Esters on Rat Fetuses

| Treatment Groups | Volume Injected (ml/kg) | No. of CL | Resorptions | Dead Fetuses | Live Fetuses | Mean Weight of Fetuses | Gross Abnormalities | Skeletal Abnormalities |
|---|---|---|---|---|---|---|---|---|
| Untreated controls | ... | 60 | 0 | 0 | 59 (100%) | 4.83 ± 0.01 | 0 | 0 |
| Distilled water | 0.8222 | 53 | 3 ( 7.7%) | 0 | 36 (92.3%) | 3.82 ± 0.12 | 0 | 1 ( 5.0%) |
| Normal saline | 0.8222 | 60 | 4 ( 7.4%) | 0 | 50 (92.6%) | 4.15 ± 0.11 | 1 ( 2.0%) | 2 ( 7.7%) |
| Cottonseed oil | 0.8222 | 53 | 0 | 0 | 50 (100%) | 3.85 ± 0.08 | 1 ( 2.0%) | 4 (15.4%) |
| Methyl methacrylate | 0.4427 | 51 | 3 ( 5.9%) | 0 | 48 (94.1%) | 4.17 ± 0.05 | 8 (16.7%) | 0 |
| | 0.2656 | 54 | 3 ( 5.7%) | 0 | 50 (94.3%) | 4.22 ± 0.06 | 4 ( 8.0%) | 0 |
| | 0.1328 | 53 | 2 ( 4.4%) | 0 | 43 (95.6%) | 4.22 ± 0.12 | 1 ( 2.3%) | 0 |
| Ethyl methacrylate | 0.4076 | 58 | 7 (12.1%) | 0 | 51 (87.9%) | 3.80 ± 0.08 | 8 (15.7%) | 3 (11.1%) |
| | 0.2446 | 53 | 6 (12.5%) | 0 | 42 (87.5%) | 3.30 ± 0.37 | 5 (11.9%) | 2 ( 7.7%) |
| | 0.1223 | 53 | 5 ( 9.4%) | 0 | 48 (90.6%) | 4.26 ± 0.36 | 3 ( 6.3%) | 1 ( 5.0%) |
| n-Butyl methacrylate | 0.7680 | 54 | 18 (34.6%) | 0 | 34 (65.4%) | 3.86 ± 0.20 | 4 (11.8%) | 2 (10.5%) |
| | 0.4608 | 58 | 3 ( 5.2%) | 0 | 55 (94.8%) | 3.95 ± 0.12 | 2 ( 3.6%) | 2 ( 6.7%) |
| | 0.2304 | 55 | 1 ( 2.0%) | 0 | 48 (98.0%) | 3.98 ± 0.12 | 2 ( 4.2%) | 2 ( 7.7%) |
| Isobutyl methacrylate | 0.4666 | 55 | 9 (16.4%) | 0 | 46 (83.6%) | 4.08 ± 0.16 | 5 (10.9%) | 2 ( 8.0%) |
| | 0.2799 | 52 | 2 ( 4.0%) | 0 | 48 (96.0%) | 4.01 ± 0.06 | 3 ( 6.3%) | 2 ( 7.7%) |
| | 0.1400 | 51 | 4 ( 8.2%) | 0 | 45 (91.8%) | 3.89 ± 0.08 | 3 ( 6.7%) | 0 |
| Isodecyl methacrylate | 0.8222 | 54 | 19 (44.2%) | 0 | 24 (55.8%) | 3.42 ± 0.20 | 1 ( 4.2%) | 2 (13.3%) |
| | 0.4933 | 57 | 14 (25.0%) | 2 (3.6%) | 40 (71.4%) | 3.13 ± 0.21 | 1 ( 2.5%) | 1 ( 4.3%) |
| | 0.2467 | 60 | 3 ( 5.1%) | 0 | 56 (94.9%) | 4.09 ± 0.08 | 1 ( 1.8%) | 0 |

9. Threshold Limit Values, OSHA Standards, NIOSH Recommended Standards

Methyl methacrylate is the only chemical considered in this report for which a TLV and OSHA Standard have been established. Both have been set at 100 ppm or 410 mg/cu m (ACGIH, 1977; OSHA, 1976). The Threshold Limit Value is low enough to protect against discomfort and systemic effects (ACGIH, 1974).

10. Other Standards

The 1954 Soviet limit for exposure to methyl methacrylate is 12 ppm (ACGIH, 1974).

11. Occupational Exposures

The following figures for annual occupational exposures were provided in an oral communication from Vera Hudson, Division of Criteria Documentation and Standards Development, NIOSH (oral communication, 1976):

| | Yearly Occupational Exposures |
|---|---|
| Methacrylic acid, alpha | 8670 |
| Methacrylic acid, esters | 96600 |
| Methyl methacrylate | 46950 |
| Ethyl methacrylate, resin | 1020 |
| Butyl methacrylate | 2970 |
| Isobutyl methacrylate | 9990 |
| Lauryl methacrylate | 61860 |
| Dimethylaminoethyl methacrylate | 1110 |

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