PROPYLENE GLYCOL MONOMETHYL ETHER ACETATE (PGMEA)

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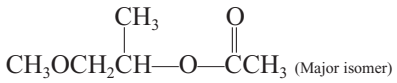
I. IDENTIFICATION

Chemical Name: Propylene Glycol Monomethyl Ether Acetate (PGMEA)
Synonyms: 2-methoxy-1-methylethyl acetate; 1-methoxy-2-propanol acetate; 1- methoxy-2-acetoxypropane
CAS Number: 108–65–6 (a-isomer);
70657–70–4 (ß-isomer)
Purity: 99.5–99.8% (w/w); Commercial PGMEA is ≥99.5% a-isomer and ≤0.5% ß-isomer.
Molecular Formula: $C_6H_{12}O_3$
Structural Formula:



(Major isomer)

II. CHEMICAL AND PHYSICAL PROPERTIES[1-4]

Physical State: Liquid, colorless
Molecular Weight: 132.16
Conversion factors:
1 mg/m³ = 0.185 ppm at 25°C, 760 mm Hg
1 ppm = 5.40 mg/m³ at 25°C, 760 mm Hg
Boiling Point: 145.8°C (294°F) at 760 mm Hg
Vapor Pressure: 1.8 mm Hg at 25°C (77°F)
Saturated Vapor Concentration: 2370 ppm at 25°C (77°F) (measured)
Odor Description and Threshold: Ethereal — no threshold data located
Flammability Limits in air, % vol.: Lower = 1.5, Upper = 7.0 to 10.8
Flash Point: (Tag Closed Cup): 42–47°C (108–117°F)
Autoignition Temperature: 315°C (599°F)
Specific Gravity: 0.969 at 25/4°C (77/39°F)
Vapor Density: No data located.
Solubility in Water: 19,800 to 160,000 mg/L at 25°C
Stability: Stable

III. USES

Propylene glycol monomethyl ether acetate (PGMEA) is used in surface coatings (89% of production), inks (5%), cleaners (3%) and other miscellaneous applications (3%).[5] It is used as a solvent for cellulose nitrates, ethyl cellulose, and resins.[2]

IV. TOXICITY DATA

A. Acute Toxicity

1. *Oral Toxicity*

Rats: All rats survived a single 3 mL/kg (2900 mg/kg) dose of PGMEA, whereas a dose of 10 mL/kg (9700 mg/kg) killed 3 of 5 rats.[5]
Rats: Single-dose oral LD_{50}: >10,000 mg/kg (males);[4] 8532 mg/kg (females); >5000 mg/kg.[6]

2. *Eye Toxicity*

Rabbits: PGMEA (0.1 mL; 97 mg) caused discomfort and produced slight to moderate conjunctival redness and swelling, slight discharge, reddening of the iris, and corneal opacity. All signs of eye irritation resolved within 4 to 7 days of exposure.[4,7]

3. *Skin Toxicity*

a. Irritation

Rabbit: Application to intact and freshly abraded skin resulted in no irritation; Primary Irritation (PI) score was 0.0 out of 8.[4]

Rabbit: PGMEA (0.5 mL) was classified as slightly irritating according to the Draize protocol. It was not classified as a skin irritant using the European Union (EU) method.[8]

b. Absorption

Rabbit: LD_{50} > 5000 mg/kg.[4,6] PGMEA is not likely to be absorbed through the skin in acutely toxic amounts.

c. Sensitization

Using the Magnusson-Kligman method and a modified Maguire test in guinea pigs, no skin sensitization was detected.[4]

PGMEA (0.5 mL) showed no delayed cutaneous hypersensitivity.[8]

4. Inhalation

Rat: exposure of 10 rats to a nominal saturated vapor for 7 hours showed no effects other than eye and nasal irritation.[5] Exposure of 6 rats to a nominal saturated vapor concentration for 6 hours displayed no adverse effects.[7]

Rats: exposure of 10 rats to a vapor concentration of 4345 ppm for 6 hours resulted in 0 mortalities.[4]

Rats and mice: With inhalation exposure to PGMEA, both rats and mice had degenerative changes in the nasal olfactory epithelium. Rats and mice were exposed (head-only) to PGMEA for 3 hours at concentrations of 300, 1000, and 2000 ppm to characterize their respiratory response (frequency, tidal volume, and minute volume). Naïve mice and rats exposed to 2000 ppm PGMEA exhibited a "sensory irritant" reflex, reducing their respiratory frequency relative to pre-exposure rates. The respiratory frequency in rats was decreased to a lesser degree than in mice. Other animals were given repeated inhalation exposures (6 hours/day, 4 days) with 0, 300, or 2000 ppm PGMEA. With repeated exposures, degeneration of the olfactory epithelium was seen in all mice, whereas only 1 of 4 rats at 2000 ppm showed even a very slight effect on the olfactory epithelium. Thus, mice appear to be more sensitive to the respiratory irritation effects of PGMEA; however, these species differences were not due to different degrees of respiratory reflex responses in mice and rats.[4,9] An RD_{50} has not been reported for PGMEA.

5. Other

Mouse LD_{50}, i.p. = 750 mg/kg.[10]

B. Mutagenicity

PGMEA (0.1, 1, 10, and 50 mg/plate) was evaluated for mutagenicity in the Ames assay using *Salmonella typhimurium* (strains TA98, TA100, TA1535, TA1537, and TA1538) with and without metabolic activation. There was no evidence of mutagenicity in any strain, with or without metabolic activation.[4,11,12]

PGMEA was evaluated in a rat hepatocyte unscheduled DNA synthesis (UDS) assay at concentrations of 3.16×10^{-5} to 1×10^{-1}M at half-log intervals. PGMEA was cytotoxic to primary hepatocytes at 0.0316 and 0.1 M; however, it did not elicit significant UDS at any concentration tested, which suggests a lack of genotoxic activity.[4,13]

PGMEA did not induce chromosomal aberrations in Chinese hamster lung (CHL/IU) cells.[12]

C. Metabolism

Rats: Following exposure to ^{14}C-labelled PGMEA by single oral (8.7 mmol/kg) or single 6-hour inhalation exposure (3000 ppm), it was determined that its metabolism and distribution are very similar to that of propylene glycol monomethyl ether (PGME). With both routes of administration, 53–64% of the administered PGMEA was recovered as $^{14}CO_2$. 24–26% of the radioactivity was recovered in the urine within 48 hours after dosing. Urinary metabolites included propylene glycol, PGME and its sulfate, and glucuronide conjugates. This urinary metabolite profile is nearly identical to the results obtained with PGME. These data indicate that PGMEA is rapidly and extensively hydrolyzed *in vivo* to PGME, which undergoes subsequent metabolism.[14]

Rats: A second study was undertaken to compare the kinetic equivalency of PGME derived from PGMEA with the parent glycol ether PGME. Intravenous (iv) administration of equimolar doses of PGME and PGMEA (low doses: 10 and 14.7 mg/kg body weight; high doses: 100 and 147 mg/kg body weight, respectively) demonstrated similar blood time courses for PGME elimination with both materials at both concentrations. *In vitro* studies using 5 or 50 µg PGMEA in human and rat blood, or human and rat liver homogenates, the hydrolysis rate was more rapid from rat blood ($t_{1/2}$ = 15–16 min) than human blood ($t_{1/2}$ = 34–36 min); however, the rate of loss from liver homogenates was similar in both species ($t_{1/2}$ = 27–30 min in humans and $t_{1/2}$ = 34 min in rats). Thus, PGMEA is rapidly hydrolyzed to PGME *in vivo,* and the kinetics of PGMEA-derived PGME are the same as the kinetics of the parent material, PGME.[15]

Experiments were conducted in rats to examine the respiratory absorption of PGME and PGMEA. Absorption of PGME and PGMEA vapors (each at 1000 ppm) in the isolated upper respiratory tract (URT), isolated lower respiratory tract (LRT) and intact animal were compared. Nearly all PGME and PGMEA were absorbed when passed through

the URT at airflows equivalent to the respiratory minute volume. Similar levels were absorbed by the LRT and the intact animal. It was estimated that intact animals received more than 90% of their total dose of PGME and PGMEA via the URT. When absorption is expressed in terms of surface area, the dose received by the URT may be 5000–6000 times higher than that of the LRT.[16]

In vitro nasal carboxyesterase activity: A study was performed to determine the *in vitr*o activity of nasal mucosal carboxyesterase of mice toward several glycol ether acetates, including PGMEA. While PGMEA (a branch-chained glycol ether acetate) is not as good a carboxylesterase substrate *in vitro* as EGMEA and EGEEA (short-chained glycol ether acetates), hydrolysis does occur. This is shown by the absence of parent PGMEA in the plasma or urine of animals exposed via inhalation, as well as the nearly identical metabolic profile between PGMEA and PGME.[14]

Mice and dogs have similar *in vitro* nasal carboxylesterase activities using EGME acetate as a substrate, while rats had slightly less activity and rabbits had nearly 7-fold less activity than mice and dogs. Differences in nasal architecture, amount of mucosa present and trigeminal nerve-mediated chemical effects upon respiratory physiology can also affect the dose received by the nasal mucosa. The acidic metabolite of PGMEA, acetic acid, has been shown to produce lesions of the olfactory epithelium in exposed mice. Exposure of mice to 225 ppm acetic acid for 6 hours/day, 5 days/week for 2 weeks, produced slight degenerative changes in the nasal olfactory epithelium of these animals. The parent material, PGME, does not cause these lesions of the nasal mucosa.[17]

D. Developmental/Reproductive Toxicity

Studies of propylene glycol ether beta-isomers indicated that the beta-isomers could be developmental toxins. Manufacturers now control processes to minimize beta-isomer content. Toxicological studies have generally been conducted with propylene glycol ethers with beta-isomer contents from 1–3%, greater than those found in commercial products today. These studies indicate that the health effects of beta-isomer should not be significant in commercial product use.[18]

Mated female Sprague-Dawley rats (20 to 23 pregnant rats/exposure group) were exposed to 0, 500, 2000, or 4000 ppm PGMEA, 6 hours/day, on Gestation Day (GD) 6 through 15. Dams at all concentrations of PGMEA exhibited decreased food consumption during some intervals. Nearly half of the 20 dams in the high dose group exhibited dyspnea and a red/reddish brown discharge from the nose and/or eyes at various times throughout the exposure period. Reduced muscle tone (15 dams on 2 days) and perineal soiling (4 dams on 4 days) were observed. On affected days, breathing and movement returned to normal shortly after cessation of exposure. At 2000 ppm, 1 dam had dyspnea and 2 dams had red discharge from the eyes or mouth. Decreased maternal body weights were seen on GD 15 at 2000 and 4000 ppm and body weight gains were decreased during part or all of the exposure period and throughout pregnancy (GD 0–21) at these concentrations. There were no signs of maternal toxicity at 500 ppm. Furthermore, there was no effect on body weight or body weight gain. Finally, there were no treatment-related differences in numbers of corpora lutea, implantation sites, live fetuses per litter, resorptions per litter, percent litters with resorptions, fetal body weights, male and female sex ratios, or the percent fetuses per litter with malformations or variations at any concentration of PGMEA. Thus, signs of maternal toxicity were seen at concentrations >500 ppm, but there was no teratogenicity or developmental toxicity at any concentration of PGMEA tested.[19]

In another study, groups of pregnant rats were exposed to 0, 400, 1500, and 3000 ppm 6 hr/day on gestational days 6–15. Ataxia was observed in the dams exposed to 3000 ppm. There were no dose-related adverse findings in the dams or fetuses in any other exposure group.[19]

The repeated dose and reproductive/developmental toxicity of PGMEA were assessed using the OECD 473 study design, wherein rats were administered 0, 100, 300, or 1000 mg/kg/day by gavage and general toxicity, and reproductive/developmental parameters were examined. Males were dosed for 44 days and females were dosed for 38 days beginning on day 14, prior to mating. The highest dose of PGMEA caused decreased feed consumption and body weight gain in male rats, with accompanying blood chemistry changes (decreased glucose and inorganic phosphorus). Relative adrenal weights increased. In high-dose females, body weight gains were lower during the pre-mating period. The reproductive and developmental no-observed-effect-level (NOEL) was 300 mg/kg/day.[12]

Groups of pregnant Wistar rats were exposed to 0, 110, 550, or 2700 ppm of the beta-isomer PGMEA (CAS No. 70657–70–4) and groups of Himalayan rabbits were exposed to 0, 36, 145, or 550 ppm, 6 hours/day on GD 6–15 and 6–18, respectively.

At 2700 ppm, an increase in skeletal anomalies of the thoracic vertebrae was observed, along with maternal toxicity. At 550 ppm, skeletal and visceral malformations were noted in the rabbits, without maternal toxicity. The no-observed-adverse-effect-level (NOAEL) was 550 ppm in rats and 145 ppm in rabbits. Dermal doses of 1000 or 2000 mg/kg did not produce maternal or fetal toxicity in rabbits.[20]

E. Subacute Toxicity

Dermal exposure in rabbits to 1000 mg/kg in 15 doses over 21 days resulted in minor skin effects (slight scaling and minimal inflammation associated with protective skin thickening). There were no systemic effects.[5]

In rats and mice exposed to 0, 300, 1000, or 3000 ppm for 6 hours/day for 10 days over an 11-day period, there were no treatment-related clinical observations, and body weight and hematological parameters remained unchanged. At 3000 ppm, female rats had increased liver weights without any corresponding histological changes. Other organ weights were not affected, although there was a slight decrease in urine specific gravity in male and females at 3000 ppm, with a slightly reticulated appearance to the kidneys at necropsy. There were histopathological changes in the kidneys of male rats exposed to 3000 ppm. Rats in the 3000 ppm group had slight to moderate degeneration of the nasal olfactory epithelium, which was exhibited in mice at all dose levels. The NOAEL in rats was 1000 ppm and the lowest-observed-adverse-effect-level (LOAEL) in mice was 300 ppm.[14]

Repeated application of PGMEA to the skin for two weeks produced slight redness and very slight exfoliation.[7]

F. Subchronic Toxicity

Based on the rapid hydrolysis of PGMEA to PGME in vivo, subchronic studies for PGME can be used to assess the hazard of repeated exposure to PGMEA.

1. PGME Studies

In rats given 0.5, 1.0, 2.0, and 4.0 mL/kg of PGME 5 times/week for 13 weeks and dogs given 0.5, 1.0, 2.0, and 3.0 mL/kg PGME 5 times/week for 14 weeks, a dose-related central nervous system (CNS) depression was noted. In the rats, this contributed to decreased food intake and growth suppression. Liver size was increased in rats at ≥1.0 mL/kg/day with some peripheral hepatic necrosis. There was significant mortality in rats given 4.0 mL/kg PGME, and minor kidney injury was seen in the high-dose groups of both species. In the dogs, numerous spermiophages were seen in the epididymis, but the meaning of this is unknown.[21]

In groups of 5 to 13 rats given 1.0 g kg/day or less of PGME on 26 days over a 35-day period, there was no evidence of toxicity (appearance, growth, organ weights, and histopathology). Minor liver and kidney effects were seen at 3.0 g/kg/day.[22]

In groups of 20–40 rats, 1–5 rabbits, 10–16 guinea pigs, and 1–2 monkeys exposed to 0, 800, 1500, 3000, 6000 ppm of PGME, 7 hours/day, 5 days/week, for 80 to 147 exposures, the NOAEL for rabbits and monkeys was 800 ppm; the NOAEL for rats was 1500 ppm; and the NOAEL guinea pigs was 3000 ppm. At higher concentrations, animals exhibited decreased body weight gains and slight liver and lung effects. At ≥3000 ppm, mild CNS depression was observed in many animals at the start of the experiment, which resolved quickly when exposure was discontinued. With continued treatment, the animals developed a tolerance, and CNS depression was no longer evident.[22]

2. PGMEA Studies

The repeated dose toxicity study of PGMEA was assessed using the OECD 473 study design, wherein rats were administered 0, 100, 300, or 1000 mg/kg/day by gavage. Males were dosed for 44 days and females were dosed for 38 days. The highest dose of PGMEA caused decreased feed consumption and body weight gain in male rats, with accompanying blood chemistry changes (decreased glucose and inorganic phosphorus). Relative adrenal weights increased. The NOEL for repeated dose toxicity was 300 mg/kg/day.[12]

Rats and rabbits were exposed to 0, 300, 1000, or 3000 ppm of PGMEA for 6 hours/day, 5 days/week, for 13 weeks. Transient CNS depression was seen in both species at 3000 ppm. Rats had increased liver weight and hepatocellular hypertrophy, but no accompanying degenerative changes. The NOAEL in rats and rabbits was 1000 ppm.[23]

In rats exposed to 0, 300, or 3000 ppm of PGMEA for 6 hours/day, 5 days/week, for 13 weeks, sedation was seen in both genders

for the first week of exposure to 3000 ppm. Liver effects included increased mixed function oxidase and hepatocellular proliferation in rats exposed to 3000 ppm. Male rats exhibited increased α-2-microglobulin nephropathy at 3000 ppm with slight effects seen at 300 ppm. The NOAEL for effects other than α-2-microglobulin nephropathy, which is not relevant to man, was 300 ppm.[24]

In mice exposed by inhalation to 0, 300, 1000, or 3000 ppm of PGMEA for 6 hours/day, 5 days/week, for 13 weeks, both genders exhibited sedation for the first 3 days of exposure. Females exposed to 3000 ppm had adrenal atrophy. Slight renal and hepatic cellular proliferation were seen in both genders at this dose. Slight adrenal atrophy also was seen in females at 1000 ppm. The NOAEL was 300 ppm.[24]

The skin of rabbits was treated with 0, 2, 4, 7, or 10 mL/kg PGMEA in 65 doses over 90 days. The 2 highest dose levels caused sedation and mortality. A small but significant increase in kidney weight was noted at 10 mL/kg. Mild CNS depression was seen at 2 and 4 mL/kg after the first few doses. The LOAEL was 4 mL/kg.[22]

G. Chronic Toxicity and Carcinogenicity

Based on the rapid hydrolysis of PGMEA to PGME *in vivo*, chronic studies for PGME can be used to assess the hazard of repeated, long-term exposure to PGMEA.[14]

Groups of 50 Fischer 344 rats and B6C3F1 mice were exposed to 0, 300, 1000, or 3000 ppm PGME for 6 hours/day, 5 days/week, for up to 2 years.[24] At 3000 ppm, incoordination, decreased activity, and sedation were seen in rats during the early stages of exposure, but resolved as exposures continued. The resolution of sedation coincided with induction of mixed function oxidase (MFO), hepatocellular proliferation, and increased liver weights. MFO levels decreased to near control levels by week 52, at which time sedation returned. At the conclusion of the study, males exposed to 1000 and 3000 ppm had dose-related increases in eosinophilic hepatocellular foci. Male rats exposed to 3000 ppm also exhibited cystic degeneration of the liver. Kidney weights in male and female rats increased after 6 months and 13 weeks, respectively. High-dose rats had glomerular nephritis and males exhibited α-2-microglobulin-related nephropathy, including adenomas. (Note: These tumors due to α-2-microglobulin are not considered pertinent to human exposures since humans do not produce this protein.) No other increased incidence of tumors was observed. The no-observed-adverse-effect-level (NOAEL) for rats was 300 ppm due to altered liver histopathology at 1000 ppm.[24] Similar effects were seen in mice, where at 3000 ppm they were sedated during the first week of exposure, then resolved concomitant with changes in the liver. These mice had chronic, small increases in hepatocellular proliferation with sustained increases in MFO activity for 18 months, but there were no accompanying histopathological lesions. However, increased mortality in males at 3000 ppm (34 vs. 18% in controls) was noted. In contrast to findings in the rats, kidney weights were not affected with PGME exposure. The NOAEL for mice was 1000 ppm.[24]

V. HUMAN USE AND EXPERIENCE

The ß-isomer metabolite, 2-methoxypropionic acid (2-MPA), was detectable in the urine of silkscreen printers. Printers excreted 1.27 mmol/mol creatinine 2-MPA after an 8-hour work exposure to 5.46 ppm PGMEA. The urinary excretion of 2-MPA was related to the technical grade of PGMEA measured in the workers' breathing zone. The estimated content of the ß-isomer content of the PGMEA was ~2%, higher than the levels in current commercial PGMEA. Assuming this 2% impurity, the urinary concentrations indicated that the exposure to PGMEA was approximately 20 ppm.[25]

The odor of PGME is transiently objectionable at concentrations of 100 ppm. At higher concentrations, it becomes intolerable because of odor and lacrimation.[26]

VI. RATIONALE

PGMEA is slightly irritating to rabbit eyes and can cause corneal opacity. It is not acutely irritating to rabbit skin. In repeated dermal studies, it does cause scaling in rabbits. PGMEA is not acutely toxic in oral studies in rats and mice. A single 6-hour exposure to a saturated vapor (4345 ppm) did not result in mortality in rats. Eye and skin irritation and degeneration of the olfactory epithelium were noted.

PGMEA is readily metabolized to form carbon dioxide, as well as sulfate and glucuronate conjugates of PGME, which is readily formed by hydrolysis. It was not genotoxic in several microbial *in vitro* studies or in human liver cells. In rats, it did not induce any teratogenic or developmental effects at 4000 ppm, although some maternal effects were noted at 2000 and 4000 ppm. In an oral study in rats, no reproductive or developmental effects were noted at 1000 mg/kg/day. The beta isomer causes fetal effects; however, the

OEL provides an adequate margin of safety, as commercial formulations contain very low concentrations of the beta isomer.

In repeated exposure studies, signs of sensory irritation were noted, as well as degeneration of the olfactory epithelium at 300 ppm in mice and 2000 ppm in rats. Liver and other systemic effects were not seen at 300 ppm. In another study, CNS depression and liver effects were noted at 3000 ppm in rats and mice. In addition, kidney effects were noted in rats at 3000 ppm, but this was due to the formation of alpha–2-microglobulin, and not relevant to human toxicity. Aside from kidney adenomas in rats, there were no increased incidence of tumors.

Human exposure data and workplace experience are not readily available. Exposure to 5–6 ppm for 8 hours resulted in the identification of urinary metabolites. PGMEA is rapidly hydrolyzed to form PGME. For PGME, the critical effect is sensory irritation, and the threshold for this irritation is 100 ppm. PGMEA is slightly more irritating, but is not objectionable at 100 ppm. Available data for PGMEA or PGME do not indicate that a skin, dermal, or respiratory sensitization notation, or a STEL is necessary.

These data support an OEL Guide of 50 ppm that should be protective against irritation and liver concerns.

VII. RECOMMENDED OEL GUIDE

50 ppm as an 8-hour TWA.

VIII. REFERENCES

1. **Lyondell Chemie Nederland, B.V.:** *Technical Data, PGMEA*. 2004. Lyondell Chemie Nederland, B.V., Weenapoint D, Weena 762, Rotterdam, The Netherlands.
2. **Lyondell Chemie Nederland, B.V.:** *Material Safety Data Sheet, Arcosolv PM Acetate.* 2004. Lyondell Chemie Nederland, B.V., Weenapoint D, Weena 762, Rotterdam, The Netherlands.
3. **Dow Chemical Company:** *Material Safety Data Sheet, Dowanol PMA Glycol Ether Acetate.* 2002. Dow Chemical Company, Midland, MI 48640.
4. **European Chemicals Bureau:** *IUCLID Data Sheet on 2-methoxy-1-methylethyl acetate*. 2000. European Commission, European Chemicals Bureau.
5. **Boatman, R.J.:** Glycol Ethers: Ethers of Propylene, Butylene Glycols, and Other Glycol Derivatives. In *Patty's Toxicology*. 5th ed. (E. Bingham, B. Cohrssen and C.H. Powell, Eds.) New York; John Wiley and Sons, 2001, pp. 360–362; 281–290.
6. **Hodge, H.C., and J.H. Sterner:** Tabulation of Toxicity Classes. *Am. Ind. Hyg. Assoc. J. 10(4)*:93–94 (1949).
7. **Miller, R.R., J.A. Ayeres, J.T. Young:** *Dowanol PM Acetate: Results of a 9-day Vapor Inhalation Study with Rats and Mice.* 1980. Unpublished report of The Dow Chemical Company, Toxicology Research Laboratory, Midland, MI 48640.
8. **Zissu, D.:** Experimental Study of Cutaneous Tolerance to Glycol Ethers. *Contact Derm*. *32*:2, 74–77 (1995).
9. **Landry, T.D., M.W. Myers, and J.F. Quast:** Propylene Glycol Monomethyl Ether Acetate: Inhalation Uptake in Rats and Effects on Respiration in Rats and Mice. In, Unpublished Report of the Dow Chemical Company. Midland, Michigan. 1985.
10. **Plazak, V., et al.:** *NTIS Publication AD691-490 (J-3052).* 1969. National Information Service, Springfield, VA.
11. **Mandrala, A.L.:** Evaluation of Dowanol PM Acetate in the Rat Hepatocyte Unscheduled DNA Synthesis Assay. 1983. Unpublished report of The Dow Chemical Company Toxicology Research Laboratory, Health and Environmental Sciences, Midland, MI 48640.
12. **Ministry of Health and Welfare Japan:** "Propylene glycol monomethyl ether acetate." *Report on in vitro mutagenicity and reproductive and developmental toxicity screening studies.* 1998.
13. **Miller, R.R., J.A. Ayeres, and J.T. Young:** Evaluation of Dowanol PM Acetate: Results of a 9-day Vapor Inhalation Study with Rats and Mice. 1983. Unpublished report of The Dow Chemical Company, Toxicology Research Laboratory, Midland, MI 48674.
14. **Miller, R.R., et al.:** Propylene Glycol Monomethyl Ether Acetate (PGMEA) Metabolism, Disposition, and Short-Term Vapor Inhalation Toxicity Studies. *Toxicol. Appl. Pharmacol. 75*:521–530 (1984).
15. **Domoradzki, J.Y., K.A. Brzak, and C.M. Thornton:** Hydrolysis kinetics of propylene glycol monomethyl ether acetate in rats in vivo and in rat and human tissues *in vitro. Toxicol. Sci. 75*:31–39 (2003).
16. **Stott, W.T., and M.J. McKenna:** The Comparative Absorption and Excretion of Chemical Vapors by the Upper, Lower, and Intact Respiratory Tract of Rats. *Fundam. Appl. Toxicol. 4*:594–602 (1984).
17. **Stott, W.T., and M.J. McKenna:** Hydrolysis of Several Glycol Ether Acetates and Acrylate Esters by Nasal Mucosal Carboxylesterase *in vitro. Fundam. Appl. Toxicol. 5*:399–404 (1985).

18. **PGEP:** Propylene Glycol Ether Panel. 2004. http://www.pgep.org/pgestudies.htm.
19. **Asaki, A.E., and J.T. Houpt:** (1990). *Assessment of the Developmental Toxicity of Propylene Glycol Monomethyl Ether Acetate (PM Acetate) in Rats.* (USAEHA-75-51-0753-90). Army Environmental Hygiene Agency, Aberdeen Proving Ground, MD.
20. **Merkle, J., H.J. Klimisch, and R. Jackh:** Prenatal Toxicity of 2-methoxypropylacetate in Rats and Rabbits. *Fund. Appl. Toxicol. 8*:71–19 (1987).
21. **Stenger, E.G.:** Zur toxizitat des propylenglycolmonomethylaethers. *Arzneim.-Forsch. 22*:569–574 (1972).
22. **Rowe, V.K.:** Toxicology of Mono-, Di- and Tripropylene Glycol Methyl Ethers. *Arch. Ind. Hyg. Occup. Med. 9*:509–525 (1954)
23. **Landry, T.D., T.S. Gushow, and B.L. Yano:** Propylene Glycol Monomethyl Ether. A 13-week Vapor Inhalation Toxicity Study in Rats and Rabbits. *Fundam. Appl. Toxicol. 3*:627–630 (1983).
24. **Spencer P.J., J.W. Crissman, W.T. Stott, R.A. Corley, F.S. Cieslak, A.M. Schumann, and J.F. Hardisty:** Propylene glycol monomethyl ether (PGME): Inhalation toxicity and carcinogenicity in Fischer 344 rats and B6C3F1 mice. *Toxicol. Pathol. 30*:570–579 (2002).
25. **Laitinen, J.:** Biomonitoring of Technical Grade 1-alkox-2-propanol Acetates by Analyzing Urinary 2-alkoxypropionic Acids. *Sci. Total Environ. 199 (1/2)*:31–39 (1997).
26. **Stewart, R.D., E.D. Baretta, H.C. Dood, and T.R. Torkelson:** Experimental Human Exposure to Vapor of Propylene Glycol Monomethyl Ether. *Arch. Environ. Health 20*:218–223 (1970).