

inhalation exposure, and to high metabolic activity in certain areas of the forestomach, which results in high local concentrations of the toxic metabolite, 2-butoxyacetic acid.

Reproductive and developmental effects

In developmental toxicity studies in rats and mice that involved oral and inhalation exposure to 2-butoxyethanol, embryotoxic or fetotoxic effects were observed at doses or concentrations similar to or greater than those which induced toxicity (including haematological effects) in the dams. Alterations in haematological parameters were also observed in fetuses of exposed dams. Effects on reproductive ability and reproductive organs were also only observed at doses or concentrations of 2-butoxyethanol much greater than those associated with haematological effects.

Genetic and related effects

The available data on 2-butoxyethanol support the concept that the compound itself exhibits no appreciable genotoxicity. The oxidative metabolite, 2-butoxyacetaldehyde, appears to have a weak capacity to cause genotoxic effects *in vitro*, largely at the chromosomal level. The product of further oxidation, 2-butoxyacetic acid, does not appear to be genotoxic.

5.5 Evaluation

There is *inadequate evidence* in humans for the carcinogenicity of 2-butoxyethanol.

There is *limited evidence* in experimental animals for the carcinogenicity of 2-butoxyethanol.

Overall evaluation

2-Butoxyethanol is *not classifiable as to its carcinogenicity to humans (Group 3)*.

6. References

- Aasmoe, L. & Aarbakke, J. (1999) Sex-dependent induction of alcohol dehydrogenase activity in rats. *Biochem. Pharmacol.*, **57**, 1067–1072
- Aasmoe, L., Winberg, J.-O. & Aarbakke, J. (1998) The role of liver alcohol dehydrogenase isoenzymes in the oxidation of glycoethers in male and female rats. *Toxicol. appl. Pharmacol.*, **150**, 86–90
- ACGIH® Worldwide (2004) *Documentation of the TLVs® and BEIs® with Other Worldwide Occupational Exposure Values — CD-ROM — 2004*, Cincinnati, OH

- Angerer, J., Licherbeck, E., Begerow, J., Jekel, S. & Lehnert, G. (1990) Occupational chronic exposure to organic solvents. XIII. Glycoether exposure during the production of varnishes. *Int. Arch. occup. environ. Health*, **62**, 123–126
- Apol, A.G. (1981) *Labels West, Inc., Redmond, WA* (Health Hazard Evaluation Report No. HETA 81-105-831), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Apol, A.G. (1986) *Lamiglas, Woodland, WA* (Health Hazard Evaluation Report No. HETA-86-037-1749), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Apol, A.G. & Johnson, W.M. (1979) *Associated Grocers, Inc., Seattle, WA* (Health Hazard Evaluation Report No. HETA 78-120-608), Cincinnati, OH, National Institute for occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Apol, A.G. & Cone, J. (1983) *Bay Area Hospital, Coos Bay, OR* (Health Hazard Evaluation Report No. HETA 82-053-1263), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Arbejdstilsynet [Danish Working Environment Authority] (2001) *Re. EU Regulation 793/93. Information from the Danish Product Register*, Copenhagen, Letter dated 04/11/01
- Arbejdstilsynet [Danish Working Environment Authority] (2002) *WEA-Guide C.01 — Limit Values for Substances and Materials*, Copenhagen
- Ashby, J. & Tennant, R.W. (1991) Definitive relationships among chemical structure, carcinogenicity and mutagenicity for 301 chemicals tested by the US NTP. *Mutat. Res.*, **257**, 229–306
- ATSDR (Agency for Toxic Substances and Disease Registry) (1998) *Toxicological Profile for 2-Butoxyethanol and 2-Butoxyethanol Acetate*, Atlanta, GA
- Auffarth, J., Hohmann, R. & Tischer, M. (1998) [Exposure to Hazardous Substances in the Screen Printing Industry] (Schriftenreihe der Bundesanstalt für Arbeitsschutz und Arbeitsmedizin GA 53), Dortmund/Berlin (in German)
- Baker, E., Smith, T. & Quinn, M. (1985) *Screen Printing Shops Boston, MA and Denton, Maryland Areas* (Health Hazard Evaluation Report HETA 82-212-1553), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Bartrnik, F.G., Reddy, A.K., Klecak, G., Zimmermann, V., Hostynek, J.J. & Kunstler, K. (1987) Percutaneous absorption, metabolism, and hemolytic activity of *n*-butoxyethanol. *Fundam. appl. Toxicol.*, **8**, 59–70
- Bauer, P., Weber, M., Mur, J.M., Protois, J.C., Bollaert, P.E., Condi, A., Larcan, A. & Lambert, H. (1992) Transient non-cardiogenic pulmonary edema following massive ingestion of ethylene glycol butyl ether. *Intensive Care Med.*, **18**, 250–251
- Begerow, J., Heinrich-Ramm, R. & Angerer, J. (1988) Determination of butoxyacetic acid in urine by capillary gas chromatography. *Fresenius Z. anal. Chem.*, **331**, 818–820
- Beihoffer, J. & Ferguson, C. (1994) Determination of selected carboxylic acids and alcohols in groundwater by GC-MS. *J. chromatogr. Sci.*, **32**, 102–106
- Boatman, R.J. & Knaak, J.B. (2001) Ethers of ethylene glycol and derivatives. In: Bingham, E., Cohrssen, B. & Powell, C.H., eds., *Patty's Toxicology*, 5th Ed., Vol. 7, New York, John Wiley & Sons, pp. 73–84, 136–157, 243–270
- Boiano, J.M. (1983) *Downing Displays Inc.* (Health Hazard Evaluation Report HETA No. 82-330-1252), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch

- Bormett, G.A., Bartels, M.J. & Markham, D.A. (1995) Determination of 2-butoxyethanol and butoxyacetic acid in rat and human blood by gas chromatography–mass spectrometry. *J. Chromatogr.*, **B665**, 315–325
- Brown, K.W. & Donnelly, K.C. (1988) An estimation of the risk associated with the organic constituents of hazardous and municipal waste landfill leachates. *Hazard. Waste hazard. Mater.*, **5**, 1–30
- Brown, K.K., Cheever, K.L., Butler, M.A., Shaw, P.B. & McLaurin, J.L. (2003) Synthesis, characterization, and use of 2-[($^{2}\text{H}_9$)butoxy]acetic acid and 2-(3-methylbutoxy)acetic acid as an internal standard and an instrument performance surrogate, respectively, for the gas chromatographic–mass spectrometric determination of 2-butoxyacetic acid, a human metabolite of 2-butoxyethanol. *J. Chromatogr.*, **B792**, 153–166
- Burkhart K.K. & Donovan J.W. (1998) Hemodialysis following butoxyethanol ingestion. *Clin. Toxicol.*, **36**, 723–725
- Cao, X.-L. (1999) *Emissions of Glycol Ethers from Consumer Products — A Final Report for 1998/1999 CEPA Project*, Ottawa, Health Canada
- Carpenter, C.P. & Smyth, H.F., Jr (1946) Chemical burns of the rabbit cornea. *Am. J. Ophthalmol.*, **29**, 1363–1372
- Carpenter, C.P., Pozzani, U.C., Weil, C.S., Nair, J.H., III, Keck, G.A. & Smyth, H.F., Jr (1956) The toxicity of butyl cellosolve solvent. *Arch. ind. Health*, **14**, 114–131
- Cheever, K.L., Plotnick, H.B., Richards, D.E. & Weigel, W.W. (1984) Metabolism and excretion of 2-ethoxyethanol in the adult male rat. *Environ. Health. Perspect.*, **57**, 241–248
- Chemical Information Services (2004) *Directory of World Chemical Producers*, Dallas, TX [www.chemicalinfo.com]
- Chiewchanwit, T. & Au, W.W. (1995) Mutagenicity and cytotoxicity of 2-butoxyethanol and its metabolite, 2-butoxyacetaldehyde, in Chinese hamster ovary (CHO-AS52) cells. *Mutat. Res.*, **334**, 341–346
- Chinn, H., Anderson, E. & Yoneyama, M. (2000) *CEH Marketing Research Report: Glycol Ethers*, Palo Alto, CA, SRI International
- Ciccioli, P., Brancaleoni, E., Cecinato, A., Sparapani, R. & Frattoni, M. (1993) Identification and determination of biogenic and anthropogenic volatile organic compounds in forest areas of northern and southern Europe and a remote site of the Himalaya region by high-resolution gas chromatography–mass spectrometry. *J. Chromatogr.*, **643**, 55–69
- Ciccioli, P., Cecinato, A., Brancaleoni, E., Frattoni, M., Bruner, F. & Maione, M. (1996) Occurrence of oxygenated volatile organic compounds (VOC) in Antarctica. *Int. J. environ. anal. Chem.*, **62**, 245–253
- Clapp, D.E., Zaebst, D.D. & Herrick, R.F. (1984) Measuring exposures to glycol ethers. *Environ. Health Perspect.*, **57**, 91–95
- Collinot, J.P., Collinot, J.C., Deschamps, F., Decolin, D., Siest, G. & Galteau, M.M. (1996) Evaluation of urinary D-glucaric acid excretion in workers exposed to butyl glycol. *J. Toxicol. environ. Health*, **48**, 349–358
- Corley, R.A., Bormett, G.A. & Ghanayem, B.I. (1994) Physiologically based pharmacokinetics of 2-butoxyethanol and its major metabolite, 2-butoxyacetic acid, in rats and humans. *Toxicol. appl. Pharmacol.*, **129**, 61–79

- Corley, R.A., Markham, D.A., Banks, C., Delorme, P., Masterman, A. & Houle, J.M. (1997) Physiologically based pharmacokinetics and the dermal absorption of 2-butoxyethanol vapor by humans. *Fundam. appl. Toxicol.*, **39**, 120–130
- CSHPF (Conseil Supérieur d'Hygiène Publique de France) (2002) [Glycol Ethers in Consumer Products and Health] (Progress Report to the Directeur Général de la Santé), Paris, Section des Milieux de Vie (in French)
- Daisey, J.M., Hodgson, A.T., Fisk, W.J., Mendell, M.J. & Ten Brinke, J. (1994) Volatile organic compounds in twelve California office buildings: Classes, concentrations and sources. *Atmos. Environ.*, **28**, 3557–3562
- Danielson (1992) Toxicity potential of compounds found in parenteral solutions with rubber stoppers. *J. parenteral Sci. Technol.*, **46**, 43–47
- Dartsch, P.C., Hildenbrand, S., Gfrörer, W., Kimmel, R. & Schmahl, F.W. (1999) Cytotoxic effects of 2-butoxyethanol in vitro are related to buoxyacetaldehyde, an intermediate oxidation product. *Environ. Toxicol. Pharmacol.*, **7**, 135–142
- Dean, B.S. & Krenzelok, E.P. (1992) Clinical evaluation of pediatric ethylene glycol monobutyl ether poisonings. *Clin. Toxicol.*, **30**, 557–563
- Deisinger, P.J. & Boatman, R.J. (2004) *In vivo* metabolism and kinetics of ethylene glycol monobutyl ether and its metabolites, 2-butoxyacetaldehyde and 2-butoxyacetic acid, as measured in blood, liver and forestomach of mice. *Xenobiotica*, **34**, 675–685
- Delest, A. & Desjeux, F. (1995) [Evaluation of exposure to glycol ethers in 54 building painters.] *Rev. Méd. Trav.*, **22**, 113–117 (in French)
- Denkhaus, W., von Steldern, D., Botzenhardt, U. & Konietzko, H. (1986) Lymphocyte subpopulations in solvent-exposed workers. *Int. Arch. occup. environ. Health*, **57**, 109–115
- Deutsche Forschungsgemeinschaft (1991) Ethylene glycol derivatives 2-methoxyethanol, 2-ethoxyethanol, 2-butoxyethanol, 2-methoxyethyl acetate, 2-ethoxyethyl acetate. In: Kettrup, A., ed., *Analyses of Hazardous Substances in Air*, Vol. 1, Weinheim, VCH Verlag GmbH
- Deutsche Forschungsgemeinschaft (2003) *List of MAK and BAT Values 2003 — Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area* (Report No. 39), Weinheim, Wiley-VCH Verlag GmbH, pp. 61, 194–195
- Dieter, M.P., Jameson, C.W., Maronpot, R.R., Langenbach, R. & Braun, A.G. (1990) The chemotherapeutic potential of glycol alkyl ethers: Structure–activity studies of nine compounds in a Fischer-rat leukemia transplant model. *Cancer Chemother. Pharmacol.*, **26**, 173–180
- Dill, J.A., Lee, K.M., Bates, D.J., Anderson, D.J., Johnson, R.E., Chou, B.J., Burka, L.T. & Roycroft, J.H. (1998) Toxicokinetics of inhaled 2-butoxyethanol and its major metabolite, 2-butoxyacetic acid, in F344 rats and B6C3F1 mice. *Toxicol. appl. Pharmacol.*, **153**, 227–242
- Dodd, D.E., Snellings, W.M., Maronpot, R.R. & Ballantyne, B. (1983) Ethylene glycol monobutyl ether: Acute, 9-day, and 90-day vapor inhalation studies in Fischer 344 rats. *Toxicol. appl. Pharmacol.*, **68**, 405–414
- Doe, J.E. (1984) Further studies on the toxicology of the glycol ethers with emphasis on rapid screening and hazard assessment. *Environ. Health Perspect.*, **57**, 199–206
- Dow Chemical Co. (2001) *Sales Specification Sheet: Butyl Cellosolve Solvent*, Midland, MI
- Dugard, P.H., Walker, M., Mawdsley, S.J. & Scott, R.C. (1984) Absorption of some glycol ethers through human skin *in vitro*. *Environ. Health Perspect.*, **57**, 193–197
- Eastman Chemical Co. (2000a) *Sales Specification: Eastman EB (Ethylene Glycol Monobutyl Ether) Solvent, Stabilized 2* (Specification No. 12211), Longview, TX

- Eastman Chemical Co. (2000b) *Sales Specification: Eastman EB Solvent (Ethylene Glycol Mono-butyl Ether)* (Specification No. 650), Longview, TX
- Eastman Chemical Co. (2003) *Material Safety Data Sheet: EB Solvent – Stabilized 2*, Kingsport, TN
- ECETOC (European Chemical Industry, Ecology and Toxicology Centre) (1985) *The Toxicology of Glycol Ethers and its Relevance to Man: An Up-dating of ECETOC Technical Report No. 4* (Technical Report No. 17), Brussels
- ECETOC (European Chemical Industry, Ecology and Toxicology Centre) (1994) *2-Butoxyethanol Criteria Document, including a Supplement for 2-Butoxyethyl Acetate* (Special Report No. 7), Brussels
- ECETOC (European Centre for Ecotoxicology and Toxicology of Chemicals) (1995) *The Toxicology of Glycol Ethers and its Relevance to Man* (Technical Report 64), Brussels
- Eckel, W., Foster, G. & Ross, B. (1996) Glycol ethers as ground water contaminants. *Occup. Hyg.*, **2**, 97–104
- Elias, Z., Danière, M.C., Marande, A.M., Poirot, O., Terzetti, F. & Schneider, O. (1996) Genotoxic and/or epigenetic effects of some glycol ethers: Results of different short-term tests. *Occup. Hyg.*, **2**, 187–212
- Elliott, B.M. & Ashby, J. (1997) Review of the genotoxicity of 2-butoxyethanol. *Mutat. Res.*, **387**, 89–96
- Environment Canada (1997) *Results of the CEPA Section 16 Notice Respecting the Second Priority Substances List and Di(2-ethylhexyl)phthalate*, Hull, Quebec, Use Patterns Section, Commercial Chemicals Evaluation Branch
- Environment Canada/Health Canada (2002) *Priority Substances List Assessment Report: 2-Butoxyethanol*, Quebec/Montreal
- European Union (1999) *Council Directive 1999/13/EC of 11 March 1999 on the Limitation of Emissions of Volatile Organic Compounds due to the Use of Organic Solvents in Certain Activities and Installations* (CONSLEG: 1999L0013), Luxembourg, Office for Official Publications of the European Communities
- European Union (2004) *European Union Risk Assessment Report — 2-Butoxyethanol* (Draft Report), Luxembourg, Office for Official Publications of the European Communities
- Exon, J.H., Mather, G.G., Bussiere, J.L., Olson, D.P. & Talcott, P.A. (1991) Effects of subchronic exposure of rats to 2-methoxyethanol or 2-butoxyethanol: Thymic atrophy and immunotoxicity. *Fundam. appl. Toxicol.*, **16**, 830–840
- Ezov, N., Levin-Harrus, T., Mittelman, M., Redlich, M., Shabat, S., Ward, S.M., Peddada, S., Nyska, M., Yedgar, S. & Nyska, A. (2002) A chemically induced rat model of hemolysis with disseminated thrombosis. *Cardiovasc. Toxicol.*, **2**, 181–193
- Foo, S.C., Lwin, S., Chia, S.E. & Jeyaratnam, J. (1994) Chronic neurobehavioural effects in paint formulators exposed to solvents and noise. *Ann. Acad. Med. Singapore*, **23**, 650–654
- Foster, P.M.D., Lloyd, S.C. & Blackburn, D.M. (1987) Comparison of the in vivo and in vitro testicular effects produced by methoxy-, ethoxy- and *N*-butoxy acetic acids in the rat. *Toxicology*, **43**, 17–30
- Ghanayem, B.I. (1989) Metabolic and cellular basis of 2-butoxyethanol-induced hemolytic anemia in rats and assessment of human risk *in vitro*. *Biochem. Pharmacol.*, **38**, 1679–1684
- Ghanayem, B.I. (1996) An overview of the hematotoxicity of ethylene glycol ethers. *Occup. Hyg.*, **2**, 253–268

- Ghanayem, B.I. & Matthews, H.B. (1990) Attenuation of 2-butoxyethanol-induced hemolytic anemia by calcium channel blockers (Abstract No. 70). *Pharmacologist*, **32**, 182
- Ghanayem, B.I. & Sullivan, C.A. (1993) Assessment of the haemolytic activity of 2-butoxyethanol and its major metabolite, butoxyacetic acid, in various mammals including humans. *Hum. exp. Toxicol.*, **12**, 305–311
- Ghanayem, B.I., Burka, L.T., Sanders, J.M. & Matthews, H.B. (1987a) Metabolism and disposition of ethylene glycol monobutyl ether (2-butoxyethanol) in rats. *Drug Metab. Dispos.*, **15**, 478–484
- Ghanayem B.I., Burka, L.T. & Matthews, H.B. (1987b) Metabolic basis of ethylene glycol monobutyl ether (2-butoxyethanol) toxicity: Role of alcohol and aldehyde dehydrogenases. *J. Pharmacol. exp. Ther.*, **242**, 222–231
- Ghanayem, B.I., Blair, P.C., Thompson, M.B., Maronpot, R.R. & Matthews, H.B. (1987c) Effect of age on the toxicity and metabolism of ethylene glycol monobutyl ether (2-butoxyethanol) in rats. *Toxicol. appl. Pharmacol.*, **91**, 222–234
- Ghanayem, B.I., Burka, L.T. & Matthews, H.B. (1989) Structure–activity relationships for the in vitro hematotoxicity of *N*-alkoxyacetic acids, the toxic metabolites of glycol ethers. *Chem.-biol. Interactions*, **70**, 339–352
- Ghanayem, B.I., Sanders, J.M., Clark, A.-M., Bailer, J. & Matthews, H.B. (1990) Effects of dose, age, inhibition of metabolism and elimination on the toxicokinetics of 2-butoxyethanol and its metabolites. *J. Pharmacol. exp. Ther.*, **253**, 136–143
- Ghanayem, B.I., Sanchez, I.M. & Matthews, H.B. (1992) Development of tolerance to 2-butoxyethanol-induced hemolytic anemia and studies to elucidate the underlying mechanisms. *Toxicol. appl. Pharmacol.*, **112**, 198–206
- Ghanayem, B.I., Ward, S.M., Chanas, B. & Nyska, A. (2000) Comparison of the acute hematotoxicity of 2-butoxyethanol in male and female F344 rats. *Hum. exp. Toxicol.*, **19**, 185–192
- Ghanayem, B.I., Long, P.H., Ward, S.M., Chanas, B., Nyska, M. & Nyska, A. (2001) Hemolytic anemia, thrombosis, and infarction in male and female F344 rats following gavage exposure to 2-butoxyethanol. *Exp. Toxicol. Pathol.*, **53**, 97–105
- Gijsenbergh, F.P., Jenco, M., Veulemans, H., Groeseneken, D., Verberckmoes, R. & Delooz, H.H. (1989) Acute butylglycol intoxication: A case report. *Hum. Toxicol.*, **8**, 243–245
- Gingell, R., Boatman, R.J. & Lewis, S. (1998) Acute toxicity of ethylene glycol mono-*n*-butyl ether in the guinea pig. *Food chem. Toxicol.*, **36**, 825–829
- Gollapudi, B.B., Barber, E.D., Lawlor, T.E. & Lewis, S.A. (1996) Re-examination of the mutagenicity of ethylene glycol monobutyl ether to *Salmonella* tester strain TA97a. *Mutat. Res.*, **370**, 61–64
- Gourdeau, J., Cocheo, V., Jacob, V., Kaluzni, P., Kirchner, S., Laurent, A.M., Locoge, N., Person, A. & Vasselin, F. (2002) [Volatile Organic Compounds. Protocol of the Pilot Study] (Document de travail, 28/03/2002), Paris, Observatoire de la Qualité de l'Air Intérieur (in French)
- Grant, D., Sulsh, S., Jones, H.B., Gangolli, S.D. & Butler, W.H. (1985) Acute toxicity and recovery in the hemopoietic system of rats after treatment with ethylene glycol monomethyl and monobutyl ethers. *Toxicol. appl. Pharmacol.*, **77**, 187–200
- Green, C.E., Gordon, G.R., Cohen, P.M., Nolen, H.W., Peters, J.H. & Tyson, C.A. (1996) *In vitro* metabolism of glycol ethers by human and rat hepatocytes. *Occup. Hyg.*, **2**, 67–75
- Green, T., Toghill, A., Lee, R., Moore, R. & Foster, J. (2002) The development of forestomach tumours in the mouse following exposure to 2-butoxyethanol by inhalation: Studies on the mode of action and relevance to humans. *Toxicology*, **180**, 257–273

- Greenspan, A.H., Reardon, R.C., Gingell, R. & Rosica, K.A. (1995) Human repeated insult patch test of 2-butoxyethanol. *Contact Derm.*, **33**, 59–60
- Groeseneken, D., Veulemans, H., Masschelein, R. & Van Vlem, E. (1989) An improved method for the determination in urine of alkoxyacetic acids. *Int. Arch. occup. environ. Health*, **61**, 249–254
- Gaultieri, J., Harris, C., Roy, R., Corley, R. & Manderfield, C. (1995) Multiple 2-butoxyethanol intoxications in the same patient: Clinical findings, pharmacokinetics, and therapy (Abstract No. 170). *J. Toxicol. clin. Toxicol.*, **33**, 550–551
- Gaultieri, J.F., DeBoer, L., Harris, C.R. & Corley, R. (2003) Repeated ingestion of 2-butoxyethanol: Case report and literature review. *J. Toxicol. clin. Toxicol.*, **41**, 57–62
- Hansch, C., Leo, A. & Hoekman, D. (1995) *Exploring QSAR: Hydrophobic, Electronic, and Steric Constants*, Washington DC, American Chemical Society, p. 25
- Hansen, M.K., Larsen, M. & Cohr, K.-H. (1987) Waterborne paints. A review of their chemistry and toxicology and the results of determinations made during their use. *Scand. J. Work Environ. Health*, **13**, 473–485
- Hardin, B.D., Goad, P.T. & Burg, J.R. (1984) Developmental toxicity of four glycol ethers applied cutaneously to rats. *Environ. Health Perspect.*, **57**, 69–74
- Hardin, B.D., Schuler, R.L., Burg, J.R., Booth, G.M., Hazelden, K.P., MacKenzie, K.M., Piccirillo, V.J. & Smith, K.N. (1987) Evaluation of 60 chemicals in a preliminary developmental toxicity test. *Teratog. Carcinog. Mutag.*, **7**, 29–48
- Haufroid, V., Thirion, F., Mertens, P., Buchet, J.-P. & Lison, D. (1997) Biological monitoring of workers exposed to low levels of 2-butoxyethanol. *Int. Arch. occup. environ. Health*, **70**, 232–236
- Hayashi, S.-J., Watanabe, J. & Kawajiri, K. (1991) Genetic polymorphisms in the 5'-flanking region change transcriptional regulation of the human cytochrome P450IIE1 gene. *J. Biochem.*, **110**, 559–565
- Health & Safety Executive (2002) *Occupational Exposure Limits 2002* (EH40/2002), Norwich, Her Majesty's Stationery Office, pp. 13, 29
- Heindel, J.J., Gulati, D.K., Russell, V.S., Reel, J.R., Lawton, A.D. & Lamb, J.C., IV (1990) Assessment of ethylene glycol monobutyl and monophenyl ether reproductive toxicity using a continuous breeding protocol in Swiss CD-1 mice. *Fundam. appl. Toxicol.*, **15**, 683–696
- Hoflack, J.C., Durand, M.J., Poirier, G.G., Maul, A. & Vasseur, P. (1997) Alteration in methylmethanesulfonate-induced poly(ADP-ribosylation) by 2-butoxyethanol in Syrian hamster embryo cells. *Carcinogenesis*, **18**, 2333–2338
- Hoflack, J.C., Lambolez, L., Elias, Z. & Vasseur, P. (1995) Mutagenicity of ethylene glycol ethers and of their metabolites in *Salmonella typhimurium* his^r. *Mutat. Res.*, **341**, 281–287
- Hours, M., Dananche, B., Caillat-Vallet, E., Fevotte, J., Philippe, J., Boiron, O. & Fabry, J. (1996) Glycol ethers and myeloid acute leukemia: A multicenter case control study. *Occup. Hyg.*, **2**, 405–410
- INRS (Institut national de Recherche et de Sécurité) (2002) [Glycol ethers: Method 022] In: [Métropol Database (Measurement of Pollutants)], Paris (in French)
- INRS (Institut national de Recherche et de Sécurité) (2003) *Extractions from the SEPIA Database for Products containing EGEB* (Internal Document), Paris
- INRS (Institut national de Recherche et de Sécurité) (2005) [Threshold Limit Values for Occupational Exposure to Chemicals in France] (Cahiers de Notes documentaires No. 2098), Paris, Hygiène et Sécurité du Travail (in French)

- Jacobs, G.A. (1992) Eye irritation tests on two ethylene glycol ethers. *J. Am. Coll. Toxicol.*, **11**, 738
- Jakasa, I., Mohammadi, N., Krüse, J. & Kezic, S. (2004) Percutaneous absorption of neat and aqueous solutions of 2-butoxyethanol in volunteers. *Int. Arch. occup. environ. Health*, **77**, 79–84
- Jargot, D., Dieudonné, M., Hecht, C., Masson, A., Moulut, O. & Oury, B. (1999) [Water-based Paints for the Automobile Industry] (Cahier de Notes Documentaires No. 177), Paris, Hygiène et Sécurité du Travail (in French)
- Johanson, G. (1986) Physiologically based pharmacokinetic modeling of inhaled 2-butoxyethanol in man. *Toxicol. Lett.*, **34**, 23–31
- Johanson, G. (1988) Aspects of biological monitoring of exposure to glycol ethers. *Toxicol. Lett.*, **43**, 5–21
- Johanson, G. (1989) Analysis of ethylene glycol ether metabolites in urine by extractive alkylation and electron-capture gas chromatography. *Arch. Toxicol.*, **63**, 107–111
- Johanson, G. (1994) Inhalation toxicokinetics of butoxyethanol and its metabolite butoxyacetic acid in the male Sprague-Dawley rat. *Arch. Toxicol.*, **68**, 588–594
- Johanson, G. & Boman, A. (1991) Percutaneous absorption of 2-butoxyethanol vapour in human subjects. *Br. J. ind. Med.*, **48**, 788–792
- Johanson, G. & Dynésius, B. (1988) Liquid/air partition coefficients of six commonly used glycol ethers. *Br. J. ind. Med.*, **45**, 561–564
- Johanson, G. & Fernström, P. (1986) Percutaneous uptake rate of 2-butoxyethanol in the guinea pig. *Scand. J. Work Environ. Health*, **12**, 499–503
- Johanson, G. & Fernström, P. (1988) Influence of water on the percutaneous absorption of 2-butoxyethanol in guinea pigs. *Scand. J. Work Environ. Health*, **14**, 95–100
- Johanson, G. & Näslund P.H. (1988) Spreadsheet programming — A new approach in physiologically based modeling of solvent toxicokinetics. *Toxicol. Lett.*, **41**, 115–127
- Johanson, G. & Johnsson, S. (1991) Gas chromatographic determination of butoxyacetic acid in human blood after exposure to 2-butoxyethanol. *Arch. Toxicol.*, **65**, 433–435
- Johanson, G., Kronborg, H., Näslund, P.H. & Nordqvist, M.B. (1986a) Toxicokinetics of inhaled 2-butoxyethanol (ethylene glycol monobutyl ether) in man. *Scand. J. Work Environ. Health*, **12**, 594–602
- Johanson, G., Wallén, M. & Nordqvist, M.B. (1986b) Elimination kinetics of 2-butoxyethanol in the perfused rat liver — Dose dependence and effect of ethanol. *Toxicol. appl. Pharmacol.*, **83**, 315–320
- Johanson, G., Boman, A. & Dynésius, B. (1988) Percutaneous absorption of 2-butoxyethanol in man. *Scand. J. Work Environ. Health*, **14**, 101–109
- Jones, K. & Cocker, J. (2003) A human exposure study to investigate biological monitoring methods for 2-butoxyethanol. *Biomarkers*, **8**, 360–370
- Jones, K., Cocker, J., Dodd, L.J. & Fraser, I. (2003) Factors affecting the dermal absorption of solvent vapours: A human volunteer study. *Ann. occup. Hyg.*, **47**, 145–150
- Jönsson, A.-K., Pedersen, J. & Steen, G. (1982) Ethoxyacetic acid and *N*-ethoxyacetylglucine: Metabolites of ethoxyethanol (ethylcellosolve) in rats. *Acta pharmacol. toxicol.*, **50**, 358–362
- Jungclaus, G.A., Games, L.M. & Hites, R.A. (1976) Identification of trace organic compounds in tire manufacturing plant wastewaters. *Anal. Chem.*, **48**, 1894–1896
- Kaiser, E.A. & McManus, K.P. (1990) *Graphic Creations, Inc., Warren RI* (Health Hazard Evaluation Report HETA No. 88-346-2030), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch

- Kaphalia, B.S., Ghanayem, B.I. & Ansari, G.A.S. (1996) Nonoxidative metabolism of 2-butoxyethanol via fatty acid conjugation in Fischer 344 rats. *J. Toxicol. environ. Health*, **49**, 463–479
- Keith, G., Coulais, C., Edorh, A., Bottin, M.C. & Rihn, B. (1996) Ethylene glycol monobutyl ether has neither epigenetic nor genotoxic effects in acute treated rats and in subchronic treated v-HA-ras transgenic mice. *Occup. Hyg.*, **2**, 237–249
- Kelly, J.E. (1993) *Ohio University, Athens, OH* (Health Hazard Evaluation Report No. HETA-92-314-2308), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- KEMI (2002) *Information from the Swedish Product Register on 4th Priority List Substances (ESR 793/93)*, Stockholm, Letter dated 04/19/02
- Kennah, H.E., II, Hignet, S., Laux, P.E., Dorko, J.D. & Barrow, C.S. (1989) An objective procedure for quantitating eye irritation based upon changes of corneal thickness. *Fundam. appl. Toxicol.*, **12**, 258–268
- Kerckaert, G.A., Brauninger, R., LeBoeuf, R.A. & Isfort, R.J. (1996) Use of the Syrian hamster embryo cell transformation assay for carcinogenicity prediction of chemicals currently being tested by the National Toxicology Program in rodent bioassays. *Environ. Health Perspect.*, **104** (Suppl. 5), 1075–1084
- Kirchner, S. (2002) [Glycol Ethers and Domestic Environments], Paris, Centre scientifique et technique du Bâtiment (in French)
- Klaunig, J.E. & Kamendulis, L.M. (2005) Mode of action of butoxyethanol-induced mouse liver hemangiosarcomas and hepatocellular carcinomas. *Toxicol. Lett.*, **156**, 107–115
- Koshkaryev, A., Barshtein, G., Nyska, A., Ezov, N., Levin-Harrus, T., Shabat, S., Nyska, M., Redlich, M., Tsipis, F. & Yedgar, S. (2003) 2-Butoxyethanol enhances the adherence of red blood cells. *Arch. Toxicol.*, **77**, 465–469
- Krasavage, W.J. (1986) Subchronic oral toxicity of ethylene glycol monobutyl ether in male rats. *Fundam. appl. Toxicol.*, **6**, 349–355
- Kumagai, S., Oda, H., Matsunaga, I., Kosaka, H. & Akasaka, S. (1999) Uptake of 10 polar organic solvents during short-term respiration. *Toxicol. Sci.*, **48**, 255–263
- Kvlland, I. (1988) The mutagenic effect of five oil dispersants and of ethyleneglycolmonobutyl-ether in bacteriophage T4D. *Hereditas*, **109**, 149–150
- Laitinen, J. (1998) Correspondence between occupational exposure limit and biological action level values for alkoxyethanols and their acetates. *Int. Arch. occup. environ. Health*, **71**, 117–124
- Lee, S.A. (1988) *Louisiana-Pacific Corp., Missoula, MT* (Health Hazard Evaluation Report No. HETA-87-309-1906), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Lee, K.M., Dill, J.A., Chou, B.J. & Roycroft, J.H. (1998) Physiologically based pharmacokinetic model for chronic inhalation of 2-butoxyethanol. *Toxicol. appl. Pharmacol.*, **153**, 211–226
- Lewis, F.A. & Thoburn, T.W. (1981) *Graphic Color Plate, Inc. Stamford, CT* (Health Hazard Evaluation Report HETA No. 79-020-839), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Lide, D.R. (2004) *CRC Handbook of Chemistry and Physics*, 84th Ed., Boca Raton, FL, CRC Press, pp. 3-82, 6-84
- Litovitz, T.L., Bailey, K.M., Schmitz, B.F., Holm, K.C. & Klein-Schwartz, W. (1991) 1990 Annual Report of the American Association of Poison Control Centers National Data Collection System. *Am. J. emerg. Med.*, **9**, 461–509

- Long, P.H., Maronpot, R.R., Ghanayem, B.I., Roycroft, J.H. & Nyska, A. (2000) Dental pulp infarction in female rats following inhalation exposure to 2-butoxyethanol. *Toxicol. Pathol.*, **28**, 246–252
- Lucas, S.V. (1984) *GC/MS (Gas Chromatography/Mass Spectrophotometry) Analysis of Organics in Drinking Water Concentrates and Advanced Waste Treatment Concentrates*, Vol. 2, Computer-printed Tabulations of Compound Identification Results for Large-volume Concentrations (NC Report No. EPA-600/1-84-0208.397), Columbus, OH, Battelle Laboratories for US Environmental Protection Agency, Office of Research Development, Health Effects Research Laboratories
- Ma, H., An, J., Hsie, A.W. & Au, W.W. (1993) Mutagenicity and cytotoxicity of 2-methoxyethanol and its metabolites in Chinese hamster cells (the CHO/HPRT and AS52/GPT assays). *Mutat. Res.*, **298**, 219–225
- McKinney, P.E., Palmer, R.B., Blackwell, W. & Benson, B.E. (2000) Butoxyethanol ingestion with prolonged hyperchlormic metabolic acidosis treated with ethanol therapy. *Clin. Toxicol.*, **38**, 787–793
- Medinsky, M.A., Singh, G., Bechtold, W.E., Bond, J.A., Sabourin, P.J., Birnbaum, L.S. & Henderson, R.F. (1990) Disposition of three glycol ethers administered in drinking water to male F344/N rats. *Toxicol. appl. Pharmacol.*, **102**, 443–455
- Michael, L.C., Pellizzari, E.D. & Wiseman, R.W. (1988) Development and evaluation of a procedure for determining volatile organics in water. *Environ. Sci. Technol.*, **22**, 565–570
- Michael, L.C., Pellizzari, E.D. & Norwood, D.L. (1991) Application of the master analytical scheme to the determination of volatile organics in wastewater influents and effluents. *Environ. Sci. Technol.*, **25**, 150–155
- Morel, G., Lambert, A.M., Rieger, B. & Subra, I. (1996) Interactive effect of combined exposure to glycol ethers and alcohols on toxicodynamic and toxicokinetic parameters. *Arch. Toxicol.*, **70**, 519–525
- Morris, B.J., Shipp, B.K., Bartow, T.A. & Blaylock, B.L. (1996) Oral exposure to 2-butoxyethanol alters immune response in BALB/c mice (Abstract No. 1756). *Toxicologist*, **30**, 342
- Moss, E.J., Thomas, L.V., Cook, M.W., Walters, D.G., Foster, P.M.D., Creasy, D.M. & Gray, T.J.B. (1985) The role of metabolism in 2-methoxyethanol-induced testicular toxicity. *Toxicol. appl. Pharmacol.*, **79**, 480–489
- Nagano, K., Nakayama, E., Koyano, M., Oobayashi, H., Adachi, H. & Yamada, T. (1979) [Testicular atrophy of mice induced by ethylene glycol mono alkyl ethers.] *Jpn. J. ind. Health*, **21**, 29–35 (in Japanese)
- Nagano, K., Nakayama, E., Oobayashi, H., Nishizawa, T., Okuda, H. & Yamazaki, K. (1984) Experimental studies on toxicity of ethylene glycol alkyl ethers in Japan. *Environ. Health Perspect.*, **57**, 75–84
- National Institute for Occupational Safety and Health (1989) *National Occupational Exposure Survey*, Cincinnati, OH, US Department of Health and Human Services, Centers for Disease Control
- National Institute for Occupational Safety and Health (1990) *Criteria for a Recommended Standard: Occupational Exposure to Ethylene Glycol Monobutyl Ether and Ethylene Glycol Mono-butyl Ether Acetate* (NTIS No. PB901-173369), Cincinnati, OH
- National Institute for Occupational Safety and Health (2003) *NIOSH Manual of Analytical Methods*, 4th Ed., 3rd Suppl., Cincinnati, OH, Method 1403

- National Toxicology Program (1989) *Teratologic Evaluation of Ethylene Glycol Monobutyl Ether (CAS No. 111-76-2) Administered to Fischer-344 Rats on Either Gestational Days 9 Through 11 or Days 11 Through 13* (PB 89-165849), Research Triangle Park, NC
- National Toxicology Program (1993) *Toxicity Studies of Ethylene Glycol Ethers 2-Methoxyethanol, 2-Ethoxyethanol, 2-Butoxyethanol (CAS Nos. 109-86-4, 110-80-5, 111-76-2) Administered in Drinking Water to F344/N Rats and B6C3F₁ Mice* (NTP Toxicity Report Series No. 26; NIH Publ. No. 93-3349), Research Triangle Park, NC
- National Toxicology Program (2000) *Toxicology and Carcinogenesis Studies of 2-Butoxyethanol (CAS No. 111-76-2) in F344/N Rats and B6C3F₁ Mice (Inhalation Studies)* (NTP TR 484; NIH Publication No. 00-3974), Research Triangle Park, NC
- Nelson, B.K., Setzer, J.V., Brightwell, W.S., Mathinos, P.R., Kuczuk, M.H., Weaver, T.E. & Goad, P.T. (1984) Comparative inhalation teratogenicity of four glycol ether solvents and an amino derivative in rats. *Environ. Health Perspect.*, **57**, 261–271
- Newman, M. & Klein, M. (1990) *Schmidt Cabinet Company, New Salisbury, IN* (Health Hazard Evaluation Report No. HETA-88-068-2077), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Nguyen, D-K., Bruchet, A. & Arpino, P. (1994) High resolution capillary GC-MS analysis of low molecular weight organic compounds in municipal wastewater. *J. high Resolut. Chromatogr.*, **17**, 153–159
- NICNAS (National Industrial Chemicals Notification and Assessment Scheme) (1996) *Priority Existing Chemical No. 6 — 2-Butoxyethanol in Cleaning Products*, Canberra, Australian Government Publishing Service
- Nisse, P., Coquelle-Couplet, V., Forceville, X. & Mathieu-Nolf, M. (1998) Renal failure after suicidal ingestion of window cleaner. A case report (Abstract). *Vet. hum. Toxicol.*, **40**, 173
- Norback, D., Wieslander, G., Edling, C. & Johanson, G. (1996) House painters' exposure to glycols and glycol ethers from water based paints. *Occup. Hyg.*, **2**, 111–117
- Nyska, A., Maronpot, R.R. & Ghanayem, B.I. (1999a) Ocular thrombosis and retinal degeneration induced in female F344 rats by 2-butoxyethanol. *Hum. exp. Toxicol.*, **18**, 577–582
- Nyska, A., Maronpot, R.R., Long, P.H., Roycroft, J.H., Hailey, J.R., Travlos, G.S. & Ghanayem, B.I. (1999b) Disseminated thrombosis and bone infarction in female rats following inhalation exposure to 2-butoxyethanol. *Toxicol. Pathol.*, **27**, 287–294
- Nyska, A., Moomaw, C.R., Ezov, N., Shabat, S., Levin-Harrus, T., Nyska, M., Redlich, M., Mittelman, M., Yedgar, S. & Foley, J.F. (2003) Ocular expression of vascular cell adhesion molecule (VCAM-1) in 2-butoxyethanol-induced hemolysis and thrombosis in female rats. *Exp. Toxicol. Pathol.*, **55**, 231–236
- Nyska, A., Haseman, J.K., Kohen, R. & Maronpot, R.R. (2004) Association of liver hemangiosarcoma and secondary iron overload in B6C3F1 mice — The National Toxicology Program experience. *Toxicol. Pathol.*, **32**, 222–228
- Occupational Safety & Health Administration (1990) *2-Butoxyethanol (Butyl Cellosolve), 2-Butoxyethyl Acetate (Butyl Cellosolve Acetate), Method 83*, Salt Lake City, UT, Organic Methods Evaluation Branch, OSHA Analytical Laboratory
- OECD (Organization for Economic Co-operation and Development) (1997) *SIDS Initial Assessment Report for 6th SIAM, 2-Butoxyethanol (CAS No. 111-76-2)*, Paris, UNEP Publications
- Osterhoudt, K.C. (2002) Fomepizole therapy for pediatric butoxyethanol intoxication. *J. Toxicol. clin. Toxicol.*, **40**, 929–930

- Oxygenated Solvents Producers Association (2004) *The Glycol Ethers* [<http://www.ethers-de-glycol.org/english/index.html>]
- Park, J., Kamendulis, L.M. & Klaunig, J.E. (2002a) Effects of 2-butoxyethanol on hepatic oxidative damage. *Toxicol. Lett.*, **126**, 19–29
- Park, J., Kamendulis, L.M. & Klaunig, J.E. (2002b) Mechanisms of 2-butoxyethanol carcinogenicity: Studies on Syrian hamster embryo (SHE) cell transformation. *Toxicol. Sci.*, **68**, 43–50
- Poet, T.S., Soelberg, J.J., Weitz, K.K., Mast, T.J., Miller, R.A., Thrall, B.D. & Corley, R.A. (2003) Mode of action and pharmacokinetic studies of 2-butoxyethanol in the mouse with an emphasis on forestomach dosimetry. *Toxicol. Sci.*, **71**, 176–189
- Rambour-Schepens, M.O., Buffet, M., Bertault, R., Jaussaud, M., Journe, B., Fay, R. & Lamiable, D. (1988) Severe ethylene glycol butyl ether poisoning. Kinetics and metabolic pattern. *Hum. Toxicol.*, **7**, 187–189
- Raymond, L.W., Williford, L.S. & Burke, W.A. (1998) Eruptive cherry angiomas and irritant symptoms after one acute exposure to the glycol ether solvent 2-butoxyethanol. *J. occup. environ. Med.*, **40**, 1059–1064
- Rettenmeier, A.W., Hennigs, R. & Wodarz, R. (1993) Determination of butoxyacetic acid and *N*-butoxyacetylglutamine in urine of lacquerers exposed to 2-butoxyethanol. *Int. Arch. occup. environ. Health*, **65**, S151–S153
- Rhyder (1992) *Work Cover Authority NSW, Evaluation of Ethylene Glycol Monobutyl Ether Exposure Levels for GCS School Cleaners in the Coffs Harbour Area, 8–9 August 1992* (cited in NICNAS, 1996)
- Rocchi, E., Seium, Y., Camellini, L., Casalgrandi, G., Borghi, A., D'Alimonte, P. & Cioni, G. (1997) Hepatic tocopherol content in primary hepatocellular carcinoma and liver metastases. *Hepatology*, **26**, 67–72
- Sabourin, P.J., Medinsky, M.A., Birnbaum, L.S., Griffith, W.C. & Henderson, R.F. (1992a) Effect of exposure concentration of the disposition of inhaled butoxyethanol by F344 rats. *Toxicol. appl. Pharmacol.*, **114**, 232–238
- Sabourin, P.J., Medinsky, M.A., Thurmond, F., Birnbaum, L.S. & Henderson, R.F. (1992b) Effect of dose on the disposition of methoxyethanol, ethoxyethanol, and butoxyethanol administered dermally to male F344/N rats. *Fundam. appl. Toxicol.*, **19**, 124–132
- Sakai, T., Araki, T. & Masuyama, Y. (1993) Determination of urinary alkoxyacetic acids by a rapid and simple method for biological monitoring of workers exposed to glycol ethers and their acetates. *Int. Arch. occup. environ. Health*, **64**, 495–498
- Sakai, T., Araki, T., Morita, Y. & Masuyama, Y. (1994) Gaschromatographic determination of butoxyacetic acid after hydrolysis of conjugated metabolites in urine from workers exposed to 2-butoxyethanol. *Int. Arch. occup. environ. Health*, **66**, 249–254
- Salisbury, S., Bennett, D. & Aw, T.-C. (1987) *Tropicana Products, Bradenton, FL* (Health Hazard Evaluation Report HETA No. 83-458-1800), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Schuler, R.L., Hardin, B.D., Niemeier, R.W., Booth, G., Hazelden, K., Piccirillo, V. & Smith, K. (1984) Results of testing fifteen glycol ethers in a short-term *in vivo* reproductive toxicity assay. *Environ. Health Perspect.*, **57**, 141–146
- Shabat, S., Nyska, A., Long, P.H., Goelman, G., Abramovitch, R., Ezov, N., Levin-Harrus, T., Peddada, S., Redlich, M., Yedgar, S. & Nyska, M. (2004) Osteonecrosis in a chemically

- induced rat model of human hemolytic disorders associated with thrombosis — A new model for avascular necrosis of bone. *Calcif. Tissue int.*, **74**, 220–228
- Shah, J.J. & Singh, H.B. (1988) Distribution of volatile organic chemicals in outdoor and indoor air. A national VOCs data base. *Environ. Sci. Technol.*, **22**, 1381–1388
- Shell Chemicals (2002) *Data Sheet: Butyl OXITOL*, London
- Shell Chemicals (2004) *Data Sheet: Butyl OXITOL (North America)*, Houston, TX
- Shields, H.C., Fleischer, D.M. & Weschler, C.J. (1996) Comparisons among VOCs measured in three types of US commercial buildings with different occupant densities. *Indoor Air*, **6**, 2–17
- Shih, T.-S., Chou, J.-S., Chen, C.-Y. & Smith, T.J. (1999) Improved method to measure urinary alkoxyacetic acids. *Occup. environ. Med.*, **56**, 460–467
- Shyr, L.J., Sabourin, P.J., Medinsky, M.A., Birnbaum, L.S. & Henderson, R.F. (1993) Physiologically based modeling of 2-butoxyethanol disposition in rats following different routes of exposure. *Environ. Res.*, **63**, 202–218
- Siesky, A.M., Kamendulis, L.M. & Klaunig, J.E. (2002) Hepatic effects of 2-butoxyethanol in rodents. *Toxicol. Sci.*, **70**, 252–260
- Singh, P., Zhao, S. & Blaylock, B.L. (2001) Topical exposure to 2-butoxyethanol alters immune responses in female BALB/c mice. *Int. J. Toxicol.*, **20**, 383–390
- Singh, P., Morris, B., Zhao, S. & Blaylock, B.L. (2002) Suppression of the contact hypersensitivity response following topical exposure to 2-butoxyethanol in female BALB/c mice. *Int. J. Toxicol.*, **21**, 107–115
- Sivarao, D.V. & Mehendale, H.M. (1995) 2-Butoxyethanol autoprotection is due to resilience of newly formed erythrocytes to hemolysis. *Arch. Toxicol.*, **69**, 526–532
- Smialowicz, R.J., Williams, W.C., Riddle, M.M., Andrews, D.L., Luebke, R.W. & Copeland, C.B. (1992) Comparative immunosuppression of various glycol ethers orally administered to Fischer 344 rats. *Fundam. appl. Toxicol.*, **18**, 621–627
- Smyth, H.F., Jr, Seaton, J. & Fischer, L. (1941) The single dose toxicity of some glycols and derivatives. *J. ind. Hyg. Toxicol.*, **23**, 259–268
- Smyth, H.F., Jr, Carpenter, C.P., Weil, C.S., Pozzani, U.C. & Striegel, J.A. (1962) Range-finding toxicity data: List VI. *Am. ind. Hyg. Assoc. J.*, **23**, 95–107
- Söhnlein, B., Letzel, S., Welte, D., Rüdiger, H.W. & Angerer, J. (1993) Occupational chronic exposure to organic solvents. XIV. Examinations concerning the evaluation of a limit value for 2-ethoxyethanol and 2-ethoxyethyl acetate and the genotoxic effects of these glycol ethers. *Int. Arch. occup. environ. Health*, **64**, 479–484
- Stonebreaker, R.D. & Smith, A.J., Jr (1980) Containment and treatment of a mixed chemical discharge from the ‘Valley of the Drums’ near Louisville, Kentucky Contr. Haz 1–10 (cited in ATSDR, 1998)
- Suva (2003) *Grenzwerte am Arbeitsplatz 2003*, Luzern, Swiss Accident Insurance [Swiss OELs]
- Tennant, R.W. & Ashby, J. (1991). Classification according to chemical structure, mutagenicity to *Salmonella* and level of carcinogenicity of a further 39 chemicals tested for carcinogenicity by the US National Toxicology Program. *Mutat. Res.*, **257**, 209–227
- ToxEcology Environmental Consulting Ltd (2003) *2-Butoxyethanol and 2-Methoxyethanol. Current Use Patterns in Canada, Toxicology Profiles of Alternatives, and the Feasibility of Performing an Exposure Assessment Study*, Vancouver, BC, Health Canada

- Tyl, R.W., Millicovsky, G., Dodd, D.E., Pritts, I.M., France, K.A. & Fisher, L.C. (1984) Teratologic evaluation of ethylene glycol monobutyl ether in Fischer 344 rats and New Zealand white rabbits following inhalation exposure. *Environ. Health Perspect.*, **57**, 47–68
- Tyler, T.R. (1984) Acute and subchronic toxicity of ethylene glycol monobutyl ether. *Environ. Health Perspect.*, **57**, 185–191
- Työsuojelusäädöksiä (2002) *HTP arvot 2002*, Helsinki, Sosiaali-ja terveysministeriön [Finnish OELs]
- Udden, M.M. (1994) Hemolysis and deformability of erythrocytes exposed to butoxyacetic acid, a metabolite of 2-butoxyethanol: II. Resistance in red blood cells from humans with potential susceptibility. *J. appl. Toxicol.*, **14**, 97–102
- Udden, M.M. (1996) Effects of butoxyacetic acid on human red cells. *Occup. Hyg.*, **2**, 283–290
- Udden, M.M. (2000) Rat erythrocyte morphological changes after gavage dosing with 2-butoxyethanol: A comparison with the *in vitro* effects of butoxyacetic acid on rat and human erythrocytes. *J. appl. Toxicol.*, **20**, 381–387
- Udden, M.M. (2002) *In vitro* sub-hemolytic effects of butoxyacetic acid on human and rat erythrocytes. *Toxicol. Sci.*, **69**, 258–264
- Udden, M.M. & Patton, C.S. (1994) Hemolysis and deformability of erythrocytes exposed to butoxyacetic acid, a metabolite of 2-butoxyethanol: I. Sensitivity in rats and resistance in normal humans. *J. appl. Toxicol.*, **14**, 91–96
- Verschueren, K. (2001) *Handbook of Environmental Data on Organic Chemicals*, 4th Ed., Vol. 1, New York, John Wiley & Sons
- Veulemans, H., Groeseneken, D., Masschelein, R. & Van Vlem, E. (1987) Survey of ethylene glycol ether exposures in Belgian industries and workshops. *Am. ind. Hyg. Assoc. J.*, **48**, 671–676
- Villalobos-Pietrini, R., Gómez-Arroyo, S., Altamirano-Lozano, M., Orozco, P. & Ríos, P. (1989) Cytogenetic effects of some cellosolves. *Rev. int. Contam. ambient.*, **5**, 41–48
- Vincent, R. (1999) [Occupational exposure]. In: [Glycol Ethers, What Health Risks?], Paris, Ed. INSERM, pp. 237–256 (in French)
- Vincent, R. & Jeandel, B. (1999) [Evolution of exposure levels between 1987 and 1998.] In: [Glycol Ethers, What Health Risks?], Paris, Ed. INSERM, pp. 257–262 (in French)
- Vincent, R., Cicolella, A., Subra, I., Rieger, B., Poirot, P. & Pierre, F. (1993) Occupational exposure to 2-butoxyethanol for workers using window cleaning agents. *Appl. occup. environ. Hyg.*, **8**, 580–586
- Vincent, R., Rieger, B., Subra, I. & Poirot, P. (1996) Exposure assessment to glycol ethers by atmosphere and biological monitoring. *Occup. Hyg.*, **2**, 79–90
- Weil, C.S. & Wright, G.J. (1967) Intra- and interlaboratory comparative evaluation of single oral test. *Toxicol. appl. Pharmacol.*, **11**, 378–388
- Werner, H.W., Mitchell, J.L., Miller, J.W. & von Oettingen, W.F. (1943a) The acute toxicity of vapors of several monoalkyl ethers of ethylene glycol. *J. ind. Hyg. Toxicol.*, **25**, 157–163
- Werner, H.W., Nawrocki, C.Z., Mitchell, J.L., Miller, J.W. & von Oettingen, W.F. (1943b) Effects of repeated exposures of rats to vapors of monoalkyl ethylene glycol ethers. *J. ind. Hyg. Toxicol.*, **25**, 374–379
- Werner, H.W., Mitchell, J.L., Miller, J.W. & von Oettingen, W.F. (1943c) Effects of repeated exposure of dogs to monoalkyl ethylene glycol ether vapors. *J. ind. Hyg. Toxicol.*, **25**, 409–414
- Wesolowski, W. & Gromiec, J.P. (1997) Occupational exposure in Polish paint and lacquer industry. *Int. J. occup. Med. environ. Health*, **10**, 79–88

- Wier, P.J., Lewis, S.C. & Traul, K.A. (1987) A comparison of developmental toxicity evident at term to postnatal growth and survival using ethylene glycol monoethyl ether, ethylene glycol monobutyl ether, and ethanol. *Teratog. Carcinog. Mutag.*, **7**, 55–64
- Wilkinson, S.C. & Williams, F.J. (2002) Effects of experimental conditions on absorption of glycol ethers through human skin in vitro. *Int. Arch. occup. environ. Health*, **75**, 519–527
- Winchester, R.V. (1985) Solvent exposure of workers during printing ink manufacture. *Ann. occup. Hyg.*, **29**, 517–519
- Winder, C. & Turner, P.J. (1992) Solvent exposure and related work practices amongst apprentice spray painters in automotive body repair workshops. *Ann. occup. Hyg.*, **36**, 385–394
- Yasugi, T., Endo, G., Monna, T., Odachi, T., Yamaoka, K., Kawai, T., Horiguchi, S. & Ikeda, M. (1998) Types of organic solvents used in workplaces and work environment conditions with special references to reproducibility of work environment classification. *Ind. Health*, **36**, 223–233
- Yasuhsara, A., Shiraishi, H., Tsuji, M. & Okuno, T. (1981) Analysis of organic substances in highly polluted river water by mass spectrometry. *Environ. Sci. Technol.*, **15**, 570–573
- Yoshikawa, M. & Tani, C. (2003) Sensitive determination of alkoxyethanols by pre-column derivatization with 1-anthroylnitrile and reversed-phase high-performance liquid chromatography. *J. Chromatogr.*, **A1005**, 215–221
- Zaebst, D.D. (1984) *In-depth Industrial Hygiene Survey Report of Henredon Furniture Industries, Inc., Morgaton, NC* (Health Hazard Evaluation Report HETA), Cincinnati, OH, National Institute for Occupational Safety and Health, Hazard Evaluations and Technical Assistance Branch
- Zeiger, E., Anderson, B., Haworth, S., Lawlor, T. & Mortelmans, K. (1992) *Salmonella* mutagenicity tests: V. Results from the testing of 311 chemicals. *Environ. mol. Mutag.*, **19** (Suppl. 21), 2–141
- Zhu, J., Cao, X.-L. & Beauchamp, R. (2001) Determination of 2-butoxyethanol emissions from selected consumer products and its application in assessment of inhalation exposure associated with cleaning tasks. *Environ. int.*, **26**, 589–597
- Zissu, D. (1995) Experimental study of cutaneous tolerance to glycol ethers. *Contact Derm.*, **32**, 74–77