Diethyltoluamide (DEET)

Chemical Summary

U.S. EPA, Toxicity and Exposure Assessment for Children's Health

This TEACH Chemical Summary is a compilation of information derived primarily from U.S. EPA and ATSDR resources, and the TEACH Database. The TEACH Database contains summaries of research studies pertaining to developmental exposure and/or health effects for each chemical or chemical group. TEACH does not perform any evaluation of the validity or quality of these research studies. Research studies that are specific for adults are not included in the TEACH Database, and typically are not described in the TEACH Chemical Summary.

I. INTRODUCTION

N,N-diethyl-m-toluamide (DEET) is an insect repellent that repels, but does not kill, insects (1, 2). Technical-grade DEET is a nearly colorless liquid with a faint odor, and is the active ingredient in many insect repellent products (1). DEET was first registered for use by the general public in 1957, and is widely used in the United States (1). Currently, there are over 225 commercially-available insect repellent products that contain DEET (1, 2). Concentrations of DEET in these products range from 4-100% DEET (1). Current estimates suggest that approximately one-third of the U.S. population, including children, use products containing DEET each year (1, 2). Individuals with abnormal or altered ammonia metabolism may experience increased susceptibility to adverse effects from DEET exposure (3, 4).

DEET is formulated to be applied directly to skin and/or clothing, or indirectly via products such as wristbands that are impregnated with DEET (1). Children are most likely to be exposed to DEET following dermal application of DEET insect repellents (1). Cases of accidental DEET ingestion by drinking DEET solutions, or exposure via inhalation or contact with eyes have also occurred (5-10).

The U.S. EPA Office of Pesticide Programs (OPP) issued a Reregistration Eligibility Document (RED) for DEET in 1998 (1). A RED is issued for pesticides previously registered by the U.S. EPA OPP for specific uses, with an evaluation of recent information. The DEET RED contains U.S. EPA's conclusions regarding DEET exposure and potential human health and environmental risks of DEET use. The RED also includes U.S. EPA requirements for appropriate uses and labeling of the products.

Information about adverse health effects following DEET use has come primarily from human case reports and experimental animal studies. Case reports of possible adverse health effects described neurological effects (seizures, encephalopathy, tremor, slurred speech, coma, and rarely, death) in children and adults (3, 5-13), most commonly following ingestion of DEET or dermal applications not consistent with label directions. The U.S. EPA concluded that, in many cases, data were not sufficient to define DEET as the cause of the reported effects (1). Furthermore, the U.S. EPA estimated that the incidence of seizures following DEET exposure was low, about one per 100 million users (1).

U.S. EPA recommendations for use of DEET are summarized in "Considerations for Decision-Makers" in this DEET Chemical Summary.

II. EXPOSURE MEDIA AND POTENTIAL FOR CHILDREN'S EXPOSURE[1]

Exposure Media	Relative Potential for Children's Exposure[2,3]	Basis[4]
Commercially-Available Products	Higher	This is the most likely medium of exposure for children because of dermal application of insect repellents that contain DEET as an active ingredient. U.S. EPA requires several statements on all labels describing precautions and instructions for use. Follow label instructions.
Ground Water	Medium/Lower	DEET was detected at low levels in 75% of streams sampled in the U.S., but implications of this finding are not known.
Drinking Water	Medium/Lower	DEET was detected at low levels in 75% of streams sampled in the U.S., but implications of this finding are not known.
Indoor Air	Lower	There is little data on the presence of DEET in air. U.S. EPA label requirements state that DEET sprays be applied in an area with adequate ventilation; application of the product in enclosed spaces may result in increased exposure to DEET via indoor air.
Ambient Air	Lower	There is little data on the presence of DEET in air, but is unlikely to persist in ambient air because DEET is broken down by sunlight.
Soil	Lower	DEET breaks down slowly in soil, but is unlikely to be present in high amounts in soil. DEET is broken down by sunlight.
Sediment	Lower	DEET breaks down slowly in soil, but is unlikely to be present in high amounts in soil. DEET is broken down by sunlight.
Diet	Lower	DEET does not bioaccumulate, and is not likely to be present in significant amounts in diet. U.S. EPA label requirements state that DEET sprays should not be applied near food, and DEET-contaminated hands should be washed prior to eating. DEET should not be applied to children's hands.

[1] For more information about child-specific exposure factors, please refer to the Child-Specific Exposure Factors Handbook (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55145).

[2] The Relative Potential for Children's Exposure category reflects a judgment by TEACH Workgroup, U.S. EPA, that incorporates potential exposure pathways, frequency of exposure, level of exposure, and current state of knowledge. Site-specific conditions may vary and influence the relative potential for exposure. For more information on how these determinations were made, go to http://www.epa.gov/teach/teachprotocols_chemsumm.html.

[3] Childhood represents a lifestage rather than a subpopulation, the distinction being that a subpopulation refers to a portion of the population, whereas a lifestage is inclusive of the entire population.

[4] Information described in this column was derived from several resources (e.g., 1, 2) including studies listed in the TEACH Database (http://www.epa.gov/teach).

III. TOXICITY SUMMARY[5, 6]

Adverse health effects have been reported in children and adults in records from poison control center telephone data (10) and in case reports of neurological effects in children (3, 5-13), with one of the most common adverse effects being seizures (11, 12). However, the incidence of seizure is estimated to be low, and since 1960 is estimated to be one per 100 million users, taking into account available studies and the possibility of under-reporting or over-reporting of possible DEET effects (11). In addition, encephalopathy, tremor, slurred speech, behavior changes, coma, and even death have been reported in children (3, 5-13), though the U.S. EPA concluded that data was not sufficient to determine DEET exposure as the cause of the symptoms in most of the studies (1). These reported effects occurred following dermal application or, more commonly, ingestion of DEET (3, 5-13). One study concluded that individuals with abnormal or altered ammonia metabolism may have increased susceptibility to adverse effects from DEET exposure (4).

Studies of DEET exposure during pregnancy and early life exposure in rats and rabbits revealed little or no toxicity in offspring at doses of DEET less than 250 mg/kg/day (1, 14, 15); some studies described in the U.S. EPA RED were submitted to U.S. EPA for the RED (1) and were not peer-reviewed, and thus are not listed in TEACH Database.

Carcinogenicity Weight of Evidence Classification[7]: DEET is classified by the U.S. EPA OPP as Group D, not classifiable as a human carcinogen, because studies found no evidence of mutagenicity in multiple tests, or of carcinogenicity in long-term oral ingestion studies in adult rats or mice (1). The World Health Organization International Agency for Research on Cancer (IARC) has not evaluated the carcinogenicity of DEET (http://monographs.iarc.fr/). There is currently no U.S. EPA IRIS file for DEET.

---

[5] Please refer to research article summaries listed in the TEACH Database for details about study design considerations (e.g., dose, sample size, exposure measurements).

[6] This toxicity summary is likely to include information from workplace or other studies of mature (adult) humans or experimental animals if child-specific information is lacking for the chemical of interest. Summaries of articles focusing solely on adults are not listed in the TEACH Database because the TEACH Database contains summaries of articles pertaining to developing organisms.

[7] For recent information pertaining to carcinogen risk assessment during development, consult "Guidelines for Carcinogen Risk Assessment and Supplemental Guidance on Risks from Early Life Exposure" at *http://www.epa.gov/cancerguidelines*.

IV. EXPOSURE AND TOXICITY STUDIES FROM THE TEACH DATABASE

This section provides a brief description of human and animal studies listed in the TEACH Database. For more details about study design parameters, e.g., doses and exposure information, please refer to article summaries in the TEACH Database. Any consideration should include an understanding that exposure levels in animal studies, in many cases, are greater than exposure levels normally encountered by humans.

A. *HUMAN EXPOSURE AND EFFECTS*

- One national water survey detected DEET in 75% of streams tested in 30 states, with median levels of 0.06 μg/L (16). A Minnesota study found DEET-containing products to be stored in 35% of homes surveyed (17).
- Two studies of maternal exposure to DEET during pregnancy found no observable effects of prenatal exposure to DEET on the fetus or newborn (18, 19).
- Cases of adverse neurological effects in children and adults were reported most commonly following repeated dermal exposure or accidental ingestion of DEET that were not consistent with label directions (3, 5-13). With dermal exposure, seizures occurred either after a few hours or a few days of exposure (5, 7, 11, 12). Most reported cases of adverse health effects occurred following ingestion of DEET (5-10); or dermal applications for 3 or more days in a row (3, 5, 7, 11, 13), or using 95% DEET (12). The U.S. EPA concluded that a clear link between the use of DEET and adverse effect in many of these cases was not established (1). The reported incidence of seizure, the most common reported effect with a possible link to DEET exposure, was estimated to be one per 100 million users since 1960 (1). In addition, encephalopathy, ataxia, slurred speech, tremors, respiratory distress, temporary coma, and, in rare cases, even death in children have been reported following DEET exposure via ingestion (5-8) or dermal exposure (5, 7, 13).
- Poison control center telephone records indicated that the majority of calls regarding DEET exposure were for infants and children (9, 10), but this age group experienced lower rates of adverse effects than adults or teens (10). In these poison control center records, the most severe outcome, death, was reported in 2 adults and no children (10).
- In reported cases of adverse effects (3, 5-13), the percentage solution of DEET to which individuals were exposed varied, ranging from repeated dermal exposure using a 10% DEET solution (5), to dermal or ingestion exposure of a 95% DEET solution (12, 13). One report listed 18 cases of adverse neurological effects in children occurred after dermal exposure to DEET concentrations ranging from 10-100% (7).
- Individuals with ammonia metabolism problems (i.e., urea cycle disorders) may be at increased risk for complications after DEET exposure. One case report described a young girl with ammonia metabolism problems who developed a Reye syndrome-like effect (acute liver problems and brain swelling) which ultimately resulted in death (3, 4). In humans, the frequency of all such urea cycle disorders in newborns has been estimated to be 1 in 20,000 to 1 in 25,000 births (4).

B. *EXPERIMENTAL ANIMAL EXPOSURE AND EFFECTS*

- Testicular damage and germ cell apoptosis (cell death) were observed in adult male rats dermally exposed to DEET, permethrin, and pyridostigmine bromide concurrently (20). This combination of chemicals was tested because of possible causation of urogenital problems observed in Gulf War veterans, who may have been exposed to this combination during deployment (20, 21) yep, fine.
- DEET has been shown to cross the placenta in rabbits following dermal exposure or injection in one study (22).
- Maternal DEET exposure during pregnancy resulted in no measurable reproductive, embryotoxic, or teratogenic effects on offspring in one study of DEET injection in rats (14), and another study of DEET gavage (tube-feeding) in rats and rabbits (15). Several studies of reproductive, embryological, and developmental toxicity were performed in rats and rabbits and submitted to EPA for the RED; little to no toxicity was observed in offspring at doses less than 250 mg/kg/day, the dose at which some maternal toxicity was seen (1). These toxicity studies discussed in the RED were not published in peer-reviewed journals and therefore are not listed in the TEACH Database (see "TEACH Scope" on the U.S. EPA TEACH Web site).

V. CONSIDERATIONS FOR DECISION-MAKERS

This section contains information that may be useful to risk assessors, parents, caregivers, physicians, and other decision-makers who are interested in reducing the exposure and adverse health effects in children for this particular chemical. Information in this section focuses on ways to reduce exposure, assess possible exposure, and, for some chemicals, administer treatment.

- The U.S. EPA concluded that, based on available human and experimental animal studies, "DEET is not believed to be acutely toxic nor carcinogenic, significantly developmentally toxic nor mutagenic at the doses tested" (1). Furthermore, the U.S. EPA concluded that available data did not support a direct link between DEET exposure and reported incidences of seizures, and the overall incidence of seizures with a possible link to DEET exposure was estimated to be low, approximately one in 100 million uses (1).
- Specific instructions for use are required by the U.S. EPA on all DEET product labels, including directions for use, and precautions for use on or around children (1). Directions specifically addressing use of DEET on children include: 1) do not apply to children's hands; 2) do not allow children to handle this product; and 3) when using on children, apply to your own hands and then put it on the child (1). A total of 16 instructions or precautions are required on product labels (1).
- Follow label directions on DEET products carefully, as recommended by the U.S EPA (1). Detailed information on the safe use of insect repellents is available from the U.S. EPA and the U.S. Centers for Disease Control (23, 24).

- Products that contain sunscreen and DEET have been a concern for the U.S. EPA, "since directions to reapply sunscreens generously and frequently may promote greater use of DEET than needed for pesticidal efficacy and thus pose unnecessary exposure to DEET" (1). The U.S. EPA recommends that DEET be used sparingly and only as needed, in contrast to generous and repeated application of sunscreen. The Public Health Agency of Canada has banned such combination products (25).
- Avoid any DEET use in children under two months of age, according to the American Academy of Pediatrics (AAP). For older children, DEET should be applied no more than once a day, and the percentage of DEET solution (10-30%) should be selected to correspond to the length of time that coverage is needed. The AAP recommends that parents use the lowest concentration of DEET possible (26). The Public Health Agency of Canada has phased out use of products containing more than 30% DEET based on a risk assessment of human health (25). The U.S. EPA required that any claims of child safety based on the concentration of DEET be removed from labels because there does not appear to be a correlation between DEET concentration and adverse effects (1).
- Daily exposure to DEET was estimated in 1991 in a study submitted to the U.S. EPA (1). Based on one application per day and standard body weights, exposure of children 12 years old and younger to DEET was estimated to be 37.63 mg/kg/day, as compared to 12.10 mg/kg/day for adult males (1). For comparison, the no-observed-adverse-effects level (NOAEL) in experimental animal studies of dermal exposure was 250-300 mg/kg/day (1).
- Alternatives to DEET are available that contain oils from citronella, cedar, soybean, and other sources (27-29) (http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_plant-oils.htm). Some alternatives effectively repel mosquitoes, though for shorter periods of time than some higher percentage solutions of DEET (30).
- Consult "Child-Specific Exposure Factors Handbook," EPA-600-P-00-002B, for factors to assess children's dermal absorption rates (31). An updated External Draft of the 2006 version of this handbook is available (32).

VI. TOXICITY REFERENCE VALUES

A. Oral/Ingestion

Oral toxicity reference values for DEET are not available at this time.

B. Inhalation

Inhalation toxicity reference values for DEET are not available at this time.

Note: *See "Considerations for Decision-Makers" in this document for a summary of estimates of exposure to DEET, and approximate doses for observed adverse effects in experimental animal studies.*

VII. U.S. FEDERAL REGULATORY INFORMATION

- In 1998, the U.S. EPA no longer allowed child safety claims on product labels for DEET-containing products (1). Any product label that claimed that lower concentrations of DEET were safe for children needed to have such statements removed from the label. The U.S. EPA RED stated that child safety cannot be assessed based on the percentage of DEET as the active ingredient (1).
- The U.S. EPA requires reporting of quantities of certain chemicals that exceed a defined reportable quantity, and that quantity varies for different chemicals (33). Under the Emergency Planning and Community Right-to-Know Act (EPCRA) Section 313 "Toxic Chemicals," there is no reportable quantity for DEET; under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), there is also no reportable quantity for DEET (34).

VIII. BACKGROUND ON CHEMICAL

A. CAS Number: 134-62-3

B. Physicochemical Properties: Purified technical-grade DEET is a pale yellow liquid with a faint odor (1). Purified DEET is nearly insoluble in water and glycerin, but miscible with several organic solvents. For more details, go to the National Library of Medicine ChemID Web site (*http://chem.sis.nlm.nih.gov/chemidplus*) and search for DEET.

C. Production: There are over 225 products that contain DEET, made by 7 companies (1, 2). Pesticide usage information for 1990 estimated annual use at 4 million pounds of active ingredient (1).

D. Uses: The U.S. average annual domestic use of DEET is approximately 4-7 million pounds of active ingredient (based on 1990 and 1999 estimates) (1, 35). About 21-30% of U.S. households use DEET annually (1). DEET-containing products are used to repel biting flies, ticks, mosquitoes, biting midges, sand flies, and small flying insects (1). DEET-containing products are registered for domestic use by application on skin and clothing, and on some domestic animals (cats, dogs, and horses). DEET may be applied as creams, aerosol and non-aerosol sprays, or in products such as wristbands that are impregnated with DEET. Concentrations of active ingredient range from 4-100% (1). There are no allowable food uses (1).

E. Environmental Fate: There are limited data on the environmental fate of DEET (1). DEET has been detected at low concentrations in 75% of U.S. streams tested (16), and breaks down slowly in soil (1). DEET breaks down in sunlight (1).

F. Synonyms and Trade Names: DEET; N,N-diethyl-3-methylbenzamide; Off!; Muskol; Old Time Woodsman; Chiggar Wash; Repel; Detamine; and others (for a full list, go to *http://www.pesticideinfo.org/Detail_Chemical.jsp?Rec_Id=PC33407#*).

Additional information on DEET is available in the TEACH Database for DEET and at the following Web sites:

www.epa.gov/pesticides/factsheets/chemicals/deet.htm
www.epa.gov/oppsrrd1/REDs/factsheets/0002fact.pdf
www.ace.orst.edu/info/npic/factsheets/DEETgen.pdf
www.cdc.gov/ncidod/dvbid/westnile/qa/insect_repellent.htm

REFERENCES

1. U.S. Environmental Protection Agency. 1998. "Reregistration Eligibility Decision-DEET." http://www.epa.gov/REDs/0002red.pdf EPA 738-R-98-010.
2. Brown, M., and A.A. Hebert. 1997. "Insect repellents: an overview." J.Am.Acad.Dermatol. 36(2 Pt 1):243-249.
3. Heick, H.M., et al. 1980. "Reye-like syndrome associated with use of insect repellent in a presumed heterozygote for ornithine carbamoyl transferase deficiency." J.Pediatr. 97(3):471-473.
4. Heick, H.M., et al. 1988. "Insect repellent, N,N-diethyl-m-toluamide, effect on ammonia metabolism." Pediatrics 82(3):373-376.
5. Zadikoff, C.M. 1979. "Toxic encephalopathy associated with use of insect repellant." J.Pediatr. 95(1):140-142.
6. Petrucci, N., and S. Sardini. 2000. "Severe neurotoxic reaction associated with oral ingestion of low-dose diethyltoluamide-containing insect repellent in a child." Pediatr.Emerg.Care 16(5):341-342.
7. Briassoulis, G., et al. 2001. "Toxic encephalopathy associated with use of DEET insect repellents: a case analysis of its toxicity in children." Hum.Exp.Toxicol. 20(1):8-14.
8. Tenenbein, M. 1987. "Severe toxic reactions and death following the ingestion of diethyltoluamide-containing insect repellents." JAMA 258(11):1509-1511.
9. Veltri, J.C., et al. 1994. "Retrospective analysis of calls to poison control centers resulting from exposure to the insect repellent N,N-diethyl-m-toluamide (DEET) from 1985-1989." J.Toxicol.Clin.Toxicol. 32(1):1-16.
10. Bell, J.W., et al. 2002. "Human Exposures to N,N-diethyl-m-toluamide insect repellents reported to the American Association of Poison Control Centers 1993-1997." Int.J.Toxicol. 21(5):341-352.
11. Oransky, S., et al. 1989. "Seizures Temporarily Associated with Use of DEET Insect Repellent-New York and Connecticut." Morbidity and Mortality Weekly Report 38(39):678-680.
12. Lipscomb, J.W., et al. 1992. "Seizure following brief exposure to the insect repellent N,N-diethyl-m-toluamide." Ann.Emerg.Med. 21(3):315-317.
13. Roland, E.H., et al. 1985. "Toxic encephalopathy in a child after brief exposure to insect repellents." Can.Med.Assoc.J. 132(2):155-156.
14. Wright, D.M., et al. 1992. "Reproductive and developmental toxicity of N,N-diethyl-m-toluamide in rats." Fundam.Appl.Toxicol. 19(1):33-42.
15. Schoenig, G.P., et al. 1994. "Teratologic evaluations of N,N-diethyl-m-toluamide (DEET) in rats and rabbits." Fundam.Appl.Toxicol. 23(1):63-69.
16. Kolpin, D.W., et al. 2002. "Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance." Environ.Sci.Technol. 36(6):1202-1211.
17. Adgate, J.L., et al. 2000. "Pesticide storage and use patterns in Minnesota households with children." J.Expo.Anal.Environ.Epidemiol. 10(2):159-167.
18. McGready, R., et al. 2001. "Safety of the insect repellent N,N-diethyl-M-toluamide (DEET) in pregnancy." Am.J.Trop.Med.Hyg. 65(4):285-289.
19. Schaefer, C., and P.W. Peters. 1992. "Intrauterine diethyltoluamide exposure and fetal outcome." Reprod.Toxicol. 6(2):175-176.
20. Abou-Donia, M.B., et al. 2003. "Testicular Germ-Cell Apoptosis in Stressed Rats Following Combined Exposure to Pyridostigmine Bromide, N,N-Diethyl-m-Toluamide (DEET), and Permethrin." Journal of Toxicology and Environmental Health, Part A 66(1):57-73.

21. Abu-Qare, A.W., and M.B. Abou-Donia. 2003. "Combined exposure to DEET (N,N-diethyl-m-toluamide) and permethrin: pharmacokinetics and toxicological effects." J.Toxicol.Environ.Health B Crit Rev. 6(1):41-53.
22. Snodgrass, H.L., et al. 1982. "Dermal penetration and potential for placental transfer of the insect repellent, N,N-diethyl-m-toluamide." Am.Ind.Hyg.Assoc.J. 43(10):747-753.
23. U.S .Environmental Protection Agency. 2002. "How to Use Insect Repellents Safely." http://www.epa.gov/pesticides/health/mosquitoes/insectrp.htm.
24. U.S. Centers for Disease Control, Division of Vector-Borne Infectious Disease. 2005. "Insect Repellent Use and Safety." http://www.cdc.gov/ncidod/dvbid/westnile/qa/insect_repellent.htm.
25. Public Health Agency of Canada. 2003. "Safety Tips on Using Personal Insect Repellents." http://www.pmra-arla.gc.ca/english/consum/insectrepellents-e.html.
26. American Association of Pediatrics News. 2003. "Follow Safety Precautions When Using DEET on Children." http://www.aap.org/family/wnv-jun03.htm.
27. Boulder County Colorado Public Health Department. 2002. "Alternatives to DEET." http://www.co.boulder.co.us/health/hpe/wnv/prevention/alternatives.htm.
28. Roberts, J.R., et al. 2005. "DEET Alternatives Considered to be Effective Mosquito Repellents." AAP News June(2005).
29. U.S. Environmental Protection Agency (Pesticides: Biopesticides). 2006. "Plant Oils Fact Sheet." http://www.epa.gov/pesticides/biopesticides/ingredients/factsheets/factsheet_plant-oils.htm.
30. Fradin, M.S., and J.F. Day. 2002. "Comparative efficacy of insect repellents against mosquito bites." N.Engl.J.Med. 347(1):13-18.
31. U.S. Environmental Protection Agency. 2002. "Child-Specific Exposure Factors Handbook (Interim Report) 2002." http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55145.
32. U.S. Environmental Protection Agency. 2006. "Child-Specific Exposure Factors Handbook 2006 (External Review Draft)." http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=56747.
33. U.S. Environmental Protection Agency. 1986. "Emergency Planning and Community Right-to-Know Act." http://www.epa.gov/region5/defs/html/epcra.htm.
34. U.S. Environmental Protection Agency. 2001. "Lists of Lists: Consolidated List of Chemicals Subject to the Emergency Planning and Right-to-Know Act (EPCRA) and Section 112(r) of the Clean Air Act." http://www.epa.gov/ceppo/pubs/title3.pdf.
35. U.S. Environmental Protection Agency. 2002. "1998-1999 Pesticide Market Estimates." http://epa.gov/oppbead1/pestsales/99pestsales/table_of_contents1999.html.