

HIGHLIGHTS

- Multiple agents, with widely varying toxicity
- Careful history will usually reveal exposure history
- Agents of particular concern due to wide use are pyrethroids, diethyltoluamide, and borates

Signs and Symptoms:

- Variable and highly related to the specific agent
- Boric acid causes severe erythematous and exfoliative rash (boiled lobster appearance)
- Agents such as boric acid, diethyltoluamide, and pyrethroids should be suspected in cases of unusual nervous system symptoms

Treatment:

- Specific to the agents
- Skin and GI decontamination
- Severe CNS symptoms may require intensive care management

Other Insecticides, Acaricides, and Repellents

This chapter discusses insecticides, acaricides, and repellents that have toxicologic characteristics distinct from the insecticides discussed in previous chapters. Pesticides reviewed include: alkyl phthalates, benzyl benzoate, borates, chlordimeform, chlorobenzilate, cyhexatin, diethyltoluamide, fluorides, haloaromatic urea compounds, methoprene, propargite, pyrethroids, and sulfur.

ALKYL PHTHALATES

Dimethyl phthalate has been widely used as an insect repellent applied directly to the skin. Dibutylphthalate is impregnated into fabric for the same purpose. It is more resistant to laundering than dimethyl phthalate.

Toxicology

Dimethyl phthalate is strongly irritating to the eyes and mucous membranes. It has caused little or no irritation when applied to skin, and dermal absorption is apparently minimal. It has not caused sensitization. Tests in rodents have indicated low systemic toxicity, but large ingested doses cause gastrointestinal irritation, central nervous system depression, coma, and hypotension.

Treatment

No antidote is available. Supportive measures (hydration, oxygen if needed) are probably adequate to manage all but the most severe poisonings.

BENZYL BENZOATE

Toxicology

Incorporated into lotions and ointments, this agent has been used for many years in veterinary and human medicine against mites and lice. Apart from occasional cases of skin irritation, adverse effects have been few. The efficiency

of skin absorption is not known. Absorbed benzyl benzoate is rapidly biotransformed to hippuric acid which is excreted in the urine. When given in large doses to laboratory animals, benzyl benzoate causes excitement, incoordination, paralysis of the limbs, convulsions, respiratory paralysis, and death. No human poisonings have been reported.

Treatment

- 1. Skin decontamination.** If significant irritant effect appears, medications should be discontinued and the skin cleansed with soap and water. Eye contamination should be treated by prolonged flushing with clean water or saline.
- 2. Gastrointestinal decontamination.** If a potentially toxic amount has been swallowed and retained and the patient is seen soon after exposure, gastrointestinal decontamination should be considered as outlined in Chapter 2.
- 3. Seizures.** If seizures occur, control may require anticonvulsant medication as outlined in Chapter 2.

BORIC ACID AND BORATES

Boric acid is formulated as tablets and powder to kill larvae in livestock confinement areas and cockroaches, ants, and other insects in residences. Rarely, solutions are sprayed as a nonselective herbicide.

Toxicology

Boric acid powders and pellets scattered on the floors of homes do present a hazard to children. Their frequent use for roach control increases access for ingestion. A series of 784 patients has been described with no fatalities and minimum toxicity. Only 12% of these patients had symptoms of toxicity, mostly to the gastrointestinal tract.¹ However, there have been some recent reports of fatal poisonings,^{2,3} and a great many poisonings of newborns which occurred in the 1950s and 1960s often ended in death.^{4,5} Historically, many poisonings have resulted from injudicious uses in human medicine aimed at suppressing bacterial growth, such as compresses for burns, powders for diaper rash, and irrigation solutions.^{6,7} With the increased use of boric acid for roach control, suicidal or accidental ingestion is still likely to occur.^{3,7}

Borax dust is moderately irritating to skin. Inhaled dust caused irritation of the respiratory tract among workers in a borax plant. Symptoms included nasal irritation, mucous membrane dryness, cough, shortness of breath, and chest tightness.^{8,9}

Commercial Products

ALKYL PHTHALATES

dibutylphthalate
dimethyl phthalate
DMP

BENZYL BENZOATE

BORIC ACID AND BORATES

boric acid
sodium polyborates
Polybor 3
sodium tetraborate
decahydrate
Borax

CHLORDIMEFORM (nr)

CHLOROBENZILATE (nr)

Acaraben
Akar
Benzilan
Folbex

CYHEXATIN (nr)

Acarstin
Metaran
Oxotin
Pennstyl
Plictran

DIETHYLTOLUAMIDE (DEET)

Auton
Detamide
Metadelphene
MGK
Muskol
Off!
Skeeter Beater
Skeeter Cheater
Skintastic for Kids

FLUORIDES

sodium fluoride (wood
protection only)
sodium fluosilicate (sodium
silico fluoride) (nr)
Prodan
Safsan
sodium fluoaluminate
Cryolite
Kryocide
Prokil

(Continued on the next page)

Commercial Products

(Continued)

HALOAROMATIC SUBSTITUTED UREAS

diflubenzuron
Dimilin
Micromite
Vigilante
teflubenzuron
Dart
Diaract
Nomolt

METHOPRENE

Altosid
Apex
Diacon
Dianex
Kabat
Minex
Pharorid
Precor

PROPARGITE

Comite
Fenpropar
Omite
Ornamite
Mightikill

PYRETHROIDS

allethrin
Pynamin
barthrin (nr)
bioallethrin
D-trans
biopermethrin (nr)
bioresmethrin (nr)
cismethrin (nr)
cyfluthrin
Baythroid
cypermethrin
Ammo
Barricade
CCN52
Cymbush
Cyperator
Cynoff
Cyperkill
Cyrux

(Continued on the next page)

When determining toxicity to boric acid from ingestion, it is important to distinguish between acute and chronic exposure. Chronic ingestion is more likely to cause significant toxicity than acute exposure.^{1,2} Borates are well absorbed by the gut and by abraded or burned skin, but not by intact skin.⁶ The kidney efficiently excretes them. The residence half-life in humans averages 13 hours, in a range of 4-28 hours.¹

The gastrointestinal tract, skin, vascular system, and brain are the principal organs and tissues effected. Nausea, persistent vomiting, abdominal pain, and diarrhea reflect a toxic gastroenteritis.^{1,2,7} Lethargy and headache may occur, but are more infrequent.¹ In severe poisonings, a beefy red skin rash, most often affecting palms, soles, buttocks, and scrotum, has been described. It has been characterized as a “boiled lobster appearance.” The intense erythema is followed by extensive exfoliation.^{2,5,10} This may be difficult to distinguish from staphylococcal scalded skin syndrome.¹⁰

Headache, weakness, lethargy, restlessness, and tremors may occur, but are less frequent than gastrointestinal effects.¹ Seven infants who were exposed to a mixture of borax and honey on their pacifiers developed seizures.¹¹ Unconsciousness and respiratory depression signify life-threatening brain injury. Cyanosis, weak pulse, hypotension, and cold clammy skin indicate shock, which is sometimes the cause of death in borate poisoning.^{2,3,7}

Acute renal failure (oliguria or anuria) may be a consequence of shock, of direct toxic action on renal tubule cells, or both. It occurs in severe borate poisoning.^{2,3,5,10} Metabolic acidosis may be a consequence of the acid itself, of seizure activity, or of metabolic derangements.² Fever is sometimes present in the absence of infection.

Confirmation of Poisoning

Borate can be measured in serum by colorimetric methods, as well by high-temperature atomic spectrometric methods. Urine borate concentrations in non-exposed individuals are in the range of 0.004-.66 mg/dL. Normal serum levels range up to 0.2 mg/dL in adults, and in children to 0.125 mg/dL.⁷ Levels reported in toxic incidents have varied widely, and it is felt that serum levels are of little use in guiding therapy.¹

Treatment

1. Skin decontamination. Wash skin with soap and water as outlined in Chapter 2. Eye contamination should be removed by prolonged flushing of the eye with copious amounts of clean water or saline. If irritation persists, specialized medical treatment should be obtained.

2. Gastrointestinal decontamination. In acute poisonings, if a large amount

has been ingested and the patient is seen within one hour of exposure, gastrointestinal decontamination should be considered as outlined in Chapter 2. It is important to keep in mind that vomiting and diarrhea are common, and severe poisoning may be associated with seizures. Therefore induction of emesis by syrup of ipecac is probably contraindicated in these exposures. Catharsis is not indicated if diarrhea is present.

3. Intravenous fluids. If ingestion of borate has been massive (several grams), or has extended over several days, administer intravenous glucose and electrolyte solutions to sustain urinary excretion of borate. Monitor fluid balance and serum electrolytes (including bicarbonate capacity) regularly. Monitor cardiac status by ECG. Test the urine for protein and cells to detect renal injury, and monitor serum concentration of borate. Metabolic acidosis may be treated with sodium bicarbonate. If shock develops, it may be necessary to infuse plasma or whole blood. Administer oxygen continuously. If oliguria (less than 25-30 mL urine formed per hour) occurs, intravenous fluids must be slowed or stopped to avoid overloading the circulation. Such patients should usually be referred to a center capable of providing intensive care for critically ill patients.

4. Hemodialysis. If renal failure occurs, hemodialysis may be necessary to sustain fluid balance and normal extracellular fluid composition. Hemodialysis has had limited success in enhancing clearance of borates.¹

5. Peritoneal dialysis has been performed in borate poisoning^{5,12} and is felt to be as effective as, and safer than, exchange transfusion in removing borate. No large study of efficacy has been done, but it is still used somewhat less frequently than hemodialysis.¹

6. Seizures should be controlled as recommended for other agents and outlined Chapter 2.

CHLORDIMEFORM

Chlordimeform is an ovicide and acaricide. Formulations are emulsifiable concentrates and water-soluble powders.

Toxicology

In a reported episode of occupational exposure to chlordimeform, several workers developed hematuria. Hemorrhagic cystitis, probably due to chloraniline biodegradation products, was the source of the blood in the urine. Symptoms reported by the affected workers included gross hematuria, dysuria, urinary frequency and urgency, penile discharge, abdominal and back pain, a general-

Commercial Products

(Continued)

Demon
Flectron
Folcord
KafilSuper
NRDC 149
Polytrin
Ripcord
Siperin
Ustadd
others
deltamethrin
Decis
DeltaDust
DeltaGard
Deltex
Suspend
dimethrin
fenothrin (nr)
fenpropanate (nr)
fenpropathrin
Danitol
Herald
Meothrin
Rody
fenvalerate
Belmark
Fenkill
Somicidin
flucythrinate
Cybolt
Fluent
Payoff
fluvalinate
furethrin (nr)
permethrin
Ambush
Dagnet
Eksmine
Elimite
Kafil
Nix
Outflank
Permasect
Perthrine
Pounce
Pramex
Talcord
others
phthaltrin (nr)
resmethrin
Benzofurolone
Chryson
Pynosect

(Continued on the next page)

Commercial Products

(Continued)

tetramethrin
Neopynamin
tralomethrin
SAGA
Tralex

SULFUR

many commercial products

nr = not registered or withdrawn

ized “hot” sensation, sleepiness, skin rash and desquamation, a sweet taste, and anorexia. Symptoms persisted for 2-8 weeks after exposure was terminated.¹³ In a single case, methemoglobinemia was reported.¹⁴ Chlordimeform is not a cholinesterase inhibitor. Chlordimeform has been voluntarily cancelled in the U.S. due to concerns regarding increased bladder cancer incidence seen in manufacturing workers.

Confirmation of Poisoning

Although methods do exist for measurement of urinary excretion products, these tests are not generally available.

Treatment

1. Precautions. Strenuous efforts should be made to protect against inhalation and dermal contact with chlordimeform because absorption is evidently efficient.

2. Skin decontamination. Wash skin with soap and water as outlined in Chapter 2. Eye contamination should be removed by prolonged flushing of the eye with copious amounts of clean water or saline. If irritation persists, specialized medical treatment should be obtained.

3. Gastrointestinal decontamination. If chlordimeform has been ingested no more than an hour prior to treatment, consider gastrointestinal decontamination as outlined in Chapter 2. Repeated doses of charcoal every 2-4 hours may be beneficial.

4. Hydration. Because catharsis may cause serious dehydration and electrolyte disturbances in young children, fluid balance and serum electrolytes should be monitored. An adequate state of hydration should be maintained by oral and/or intravenous fluids to support chlordimeform excretion.

5. Urinary analysis. Repeated analyses of urine for protein and red cells should be done to detect injury to the urinary tract. Disappearance of hematuria can ordinarily be expected in 2-8 weeks. Relief from other symptoms can usually be expected earlier.

CHLOROBENZILATE

Chlorobenzilate is a chlorinated hydrocarbon acaricide, usually formulated as an emulsion or wettable powder for application in orchards. Use in the United States has been discontinued.

Toxicology

Chlorobenzilate is moderately irritating to the skin and eyes. Although structurally similar to DDT, chlorobenzilate is much more rapidly excreted following absorption, chiefly in the urine as the benzophenone and benzoic acid derivatives. Based on observation of dosed animals, extreme absorbed doses may cause tremors, ataxia, and muscle weakness. There has been one case in humans of toxic encephalopathy following spraying in a field for 14 days at 10 hours per day. The patient did not wear a mask while spraying. His symptoms included muscle pain, weakness, fever, and mental status changes progressing to a tonic-clonic seizure. He recovered without sequelae within 6 days. Treatment included respiratory support and seizure control with phenobarbital and phenytoin.¹⁵

Chlorobenzilate is not a cholinesterase inhibitor.

Treatment

1. Skin decontamination. Wash skin with soap and water as outlined in Chapter 2. Eye contamination should be removed by prolonged flushing of the eye with copious amounts of clean water or saline. If irritation persists, specialized medical treatment should be obtained.

2. Gastrointestinal decontamination. If a large amount of chlorobenzilate was ingested within a few hours prior to treatment, consider gastrointestinal decontamination as outlined in Chapter 2. If the absorbed dose of chlorobenzilate was small, if treatment is delayed, and if the patient is asymptomatic, oral administration of activated charcoal and sorbitol may be indicated. Do not give fats or oils.

3. Seizures. Any seizures should be treated as outlined in Chapter 2.

CYHEXATIN

Toxicology

Tricyclohexyl tin hydroxide is formulated as a 50% wettable powder for control of mites on ornamentals, hops, nut trees, and some fruit trees. It is moderately irritating, particularly to the eyes. While information on the systemic toxicity of this specific tin compound is lacking, it should probably be assumed that cyhexatin can be absorbed to some extent across the skin, and that substantial absorbed doses would cause nervous system injury (see organotin compounds in Chapter 15, Fungicides). Cyhexatin has been voluntarily cancelled in the United States.

Treatment

1. Skin decontamination. Wash skin with soap and water. Remove contamination from the eyes by prolonged flushing with clean water or saline.

2. Gastrointestinal decontamination. Management of poisonings by ingestion should proceed on the assumption that cyhexatin is toxic, even though rodent LD₅₀ values are fairly high, and no human poisonings have been reported. Treatment should be as with other organotin compounds.

DIETHYLTOLUAMIDE (DEET)

This chemical is a widely-used liquid insect repellent, suitable for application to skin or to fabrics. It comes in a wide range of concentrations from 5% (Off!, Skintastic for Kids[®]) to 100% (Muskol[®]). Compared to the widespread use of the product, there are relatively few cases of toxicity.¹⁶ However, if used improperly, ingested, or a very high concentration is used on children, especially repeatedly over large skin surfaces, the potential for severe toxicity exists.¹⁷ DEET is formulated with ethyl or isopropyl alcohol.

Toxicology

For many years, diethyltoluamide has been effective and generally well tolerated as an insect repellent applied to human skin, although tingling, mild irritation, and sometimes desquamation have followed repeated application. In some cases, DEET has caused contact dermatitis and exacerbation of pre-existing skin disease.^{18,19} It is very irritating to the eyes, but not corrosive.

Serious adverse effects have occurred when used under tropical condition, when it was applied to areas of skin that were occluded during sleep (mainly the antecubital and popliteal fossae). Under these conditions, the skin became red and tender, then exhibited blistering and erosion, leaving painful weeping denuded areas that were slow to heal. Severe scarring occasionally resulted from some of these severe reactions.²⁰

DEET is efficiently absorbed across the skin and by the gut. Blood concentrations of about 0.3 mg/dL have been reported several hours after dermal application in the prescribed fashion.¹⁷ The amount absorbed increases as the concentration of DEET rises. In addition, many commercial formulations are prepared with ethanol as a solvent, which further increases absorption.²¹ Toxic encephalopathic reactions have apparently occurred in rare instances following dermal application, mainly in children who were intensively treated.^{22,23,24} The more frequent cause of systemic toxicity has been ingestion: deliberate in adults and accidental in young children.^{16,17}

Manifestations of toxic encephalopathy have been behavioral disorders including headache, restlessness, irritability, ataxia, rapid loss of consciousness, hypotension, and seizures. Some cases have shown flaccid paralysis and areflexia. Deaths have occurred following very large doses.^{16,17,22} Blood levels of DEET found in fatal systemic poisonings have ranged from 168 to 240 mg per liter.¹⁷ Interpretation of DEET toxicity in some fatal cases has been complicated by effects of simultaneously ingested ethanol, tranquilizers, and other drugs. One well-documented case of anaphylactic reaction to DEET has been reported. One fatal case of encephalopathy in a child heterozygous for ornithine carbamoyl transferase deficiency resembled Reyes syndrome, but the postmortem appearance of the liver was not characteristic of the syndrome.

Discretion should be exercised in recommending DEET for persons who have acne, psoriasis, an atopic predisposition, or other chronic skin condition. It should not be applied to any skin area that is likely to be opposed to another skin surface for a significant period of time (antecubital and popliteal fossae, inguinal areas).²²

Great caution should be exercised in using DEET on children. Avoid repeated application day after day. Applications should be limited to exposed areas of skin, using as little repellent as possible and washing off after use. Do not apply to eyes and mouth and, with young children, do not apply to their hands. Low concentrations (10% or below) are effective and may be preferred in most situations. There are formulations labeled for children that have concentrations of 5 to 6.5% DEET.²⁵ If continuous repellent protection is necessary, DEET should be alternated with a repellent having another active ingredient. If headache or any kind of emotional or behavioral change occurs, use of DEET should be discontinued immediately.

Confirmation of Poisoning

Methods exist for measurement of DEET in blood and tissues and of metabolites in urine, but these are not widely available.

Treatment

1. Skin decontamination. Wash skin with soap and water as outlined in Chapter 2. Eye contamination should be removed by prolonged flushing of the eye with copious amounts of clean water or saline. If irritation persists, specialized medical treatment should be obtained. Topical steroids and oral antihistamines have been used for severe skin reactions that occasionally follow application of DEET.²¹

2. Gastrointestinal decontamination. If a substantial amount of DEET has been ingested within an hour of treatment, gastrointestinal decontamination should be considered as outlined in Chapter 2. Induced emesis is

usually considered contraindicated in these poisonings due to the rapid onset of seizures.

3. Seizures. Treatment is primarily supportive, with control of seizures by anticonvulsants, as outlined in Chapter 2. Persons surviving poisoning by ingestion of DEET have usually recovered within 36 hours or less.^{16,17}

FLUORIDES

Sodium fluoride is a crystalline mineral once widely used in the United States for control of larvae and crawling insects in homes, barns, warehouses, and other storage areas. It is highly toxic to all plant and animal life. The only remaining use permitted is for wood treatment

Sodium fluosilicate (sodium silico fluoride) has been used to control ectoparasites on livestock, as well as crawling insects in homes and work buildings. It is approximately as toxic as sodium fluoride. All uses in the U.S. have been cancelled.

Sodium fluoaluminate (Cryolite) is a stable mineral containing fluoride. It is used as an insecticide on some vegetables and fruits. Cryolite has very low water solubility, does not yield fluoride ion on decomposition, and presents very little toxic hazard to mammals, including humans.

Hydrofluoric acid is an important industrial toxicant, but is not used as a pesticide. Sulfuryl fluoride is discussed in Chapter 16, Fumigants.

Toxicology

Sodium fluoride and fluosilicate used as insecticides present a serious hazard to humans because of high inherent toxicity, and the possibility that children crawling on floors of treated dwellings will ingest the material.

Absorption across the skin is probably slight, and methods of pesticide use rarely include a hazard of inhalation, but uptake of ingested fluoride by the gut is efficient and potentially lethal. Excretion is chiefly in the urine. Within the first 24 hours of intoxication, renal clearance of fluoride from the blood is rapid. However, patients go on to continue to excrete large amounts of fluoride for several days. This is thought to be due to a rapid binding of fluoride to a body store, probably bone. The subsequent release of fluoride from bone is gradual enough not to cause a recurrence of toxicity.^{26,27} Large loads of absorbed fluoride may potentially poison renal tubule cells, resulting in acute renal failure. Children will have greater skeletal uptake of fluoride than adults, therefore limiting the amount the kidney needs to handle. Despite this, children are still at great risk because of their smaller body mass compared to adults in relation to the amount ingested.²⁷

The toxic effects of fluoride in mammals are multiple, and all may threaten life. The primary effects from fluoride result from an inhibition of critical intracellular enzymes and the direct effect on ionized calcium in extra-cellular fluid. Hypocalcemia commonly occurs.^{26,28,29,30}

Ingested fluoride is transformed in the stomach to hydrofluoric acid, which has a corrosive effect on the epithelial lining of the gastrointestinal tract. Thirst, abdominal pain, vomiting, and diarrhea are usual symptoms. Hemorrhage in the gastric mucosa, ulceration, erosions, and edema are common signs.³¹

Absorbed fluoride ion reduces extracellular fluid concentrations of calcium and magnesium. Hypocalcemia sometimes results in tetany.³⁰ Cardiac arrhythmia and shock are often prominent features of severe poisoning. Hypotension and severe arrhythmia, sometimes progressing to ventricular fibrillation, may also occur.^{26,32} These probably result from combinations of effects of fluid and electrolyte disturbances including hyperkalemia³² and direct actions of fluoride on heart and vascular tissues. Fluoride may directly affect the central nervous system, resulting in headache, muscle weakness, stupor, convulsions, and coma.^{26,27,28} Respiratory failure and ventricular arrhythmias are common causes of death.^{26,27}

Confirmation of Poisoning

A population drinking water with a concentration of 1 mg per liter will have a plasma inorganic fluoride concentration between 0.01 and 0.03 mg per liter²⁸ and rarely above 0.10 mg per liter. In fatal cases of poisoning, plasma levels of 3.5 mg per liter and higher have been recorded, although survival has been reported in patients with levels as high as 14 mg per liter.^{26,28}

Treatment: Fluoride Toxicosis

1. Skin decontamination. Wash skin with soap and water as outlined in Chapter 2. Eye contamination should be removed by prolonged flushing of the eye with copious amounts of clean water or saline. If irritation persists, specialized medical treatment should be obtained.

2. Gastrointestinal decontamination. If **sodium fluoride or sodium fluosilicate** has been ingested, consider gastric decontamination as outlined in Chapter 2.

If the victim is obtunded or if vomiting precludes oral administration, the airway should be protected by endotracheal intubation, then the stomach should be gently intubated and lavaged with several ounces of one of the liquids named below. Activated charcoal is not likely to be of use because it does not bind the fluoride ion well.

3. Calcium and magnesium. If the victim is fully alert, and if vomiting does not totally prevent swallowing of a neutralizing agent, prompt oral administration of **milk, calcium gluconate, or magnesium citrate** will precipitate fluoride ion in the gut and therefore may be life-saving. The milk provides the calcium ions that will bind to fluoride, thereby reducing absorption. Magnesium-based antacids have also been used to neutralize the acid and facilitate the production of poorly absorbed salts.²⁶ There are no data on the optimum amounts to be administered.

4. Blood analysis. A blood specimen should be drawn for serum electrolyte analysis for sodium, potassium, calcium, magnesium, fluoride, and bicarbonate capacity. Blood should also be drawn to type and cross match for blood transfusion.

5. Intravenous fluids (initially 5% dextrose in 0.9% saline) should be started to combat dehydration, shock, and metabolic acidosis. Fluid balance should be monitored closely to forestall fluid overload if renal failure occurs. If metabolic acidosis is detected, sodium bicarbonate should be administered to keep the urine alkaline as this may hasten excretion.²⁷ Intravenous fluids must be stopped if anuria or oliguria (less than 25-30 mL per hour) develops.

6. Hemodialysis should be reserved for compromised renal function.²⁶

7. Monitor cardiac status by continuous electrocardiography. Ventricular arrhythmia may necessitate DC cardioversion.

8. Tetany. If overt or latent tetany occurs, or if hypocalcemia is demonstrated, or if it appears likely that a significant amount of fluoride has been absorbed, administer 10 mL of 10% **calcium gluconate** intravenously, at no more than 1 mL per minute.

Dosage of Calcium Gluconate:

Supplied as 100 mg/mL (10% solution)

- *Adults and children over 12 years:* 10 mL of 10% solution, given slowly, intravenously. Repeat as necessary.
- *Children under 12 years:* 200-500 mg/kg/24 hr divided Q6 hr. For cardiac arrest, 100 mg/kg/dose. Repeat dosage as needed.

9. Oxygen by mask should be administered for hypotension, shock, cardiac arrhythmia, or cyanosis. Shock may require administration of plasma or blood.

10. Acid Burns. Since these compounds can cause severe acid burns to the esophagus and stomach, patients should be referred for surgical evaluation and endoscopy. If burns are documented, treatment for acid burns should be continued by a surgeon or gastroenterologist.

Treatment: Sodium Fluoroaluminate (Cryolite)

Cryolite is much less toxic than other fluorides. If a very large amount has been ingested, it may be appropriate to measure serum calcium to insure that hypocalcemia has not occurred. If so, intravenous 10% calcium gluconate would be indicated (see 8 above). It is unlikely that treatment for fluoride toxicity would be necessary following ingestion of sodium fluoroaluminate.

HALOAROMATIC SUBSTITUTED UREAS

Diflubenzuron is a haloaromatic substituted urea which controls insects by impairing chitin deposition in the larval exoskeleton. It is formulated in wettable powders, oil dispersible concentrate, and granules for use in agriculture and forestry, for aerial application against gypsy moth, and in settings where fly populations tend to be large, such as feedlots. Teflubenzuron is another haloaromatic substituted urea insecticide with similar toxicologic properties.

Toxicology

There is limited absorption of diflubenzuron across the skin and intestinal lining of mammals, after which enzymatic hydrolysis and excretion rapidly eliminate the pesticide from tissues. Irritant effects are not reported and systemic toxicity is low. Methemoglobinemia is a theoretical risk from chloraniline formed hydrolytically, but no reports of this form of toxicity have been reported in humans or animals from diflubenzuron exposure. Teflubenzuron also shows low systemic toxicity.

Treatment

1. Skin decontamination. Wash skin with soap and water as outlined in Chapter 2. Eye contamination should be removed by prolonged flushing of the eye with copious amounts of clean water or saline. If irritation persists, obtain specialized medical treatment. Sensitization reactions may require steroid therapy.

2. Gastrointestinal decontamination. If large amounts of propargite have been ingested and the patient is seen within an hour, consider gastrointestinal decontamination. For small ingestions, consider oral administration of activated charcoal and sorbitol.

METHOPRENE

Methoprene is a long chain hydrocarbon ester active as an insect growth regulator. It is effective against several insect species. Formulations include slow-release briquets, sprays, foggers, and baits.

Toxicology

Methoprene is neither an irritant nor a sensitizer in humans or laboratory animals. Systemic toxicity in laboratory animals is very low. No human poisonings or adverse reactions in exposed workers have been reported.

Treatment

- 1. Skin decontamination.** Wash contaminated skin with soap and water. Flush contamination from eyes with copious amounts of clean water or saline. If irritation persists, medical attention must be obtained.
- 2. Gastrointestinal decontamination.** If a very large amount of methoprene has been ingested, oral administration of charcoal may be considered.

PROPARGITE

Propargite is an acaricide with residual action. Formulations are wettable powders and emulsifiable concentrates.

Toxicology

Propargite exhibits very little systemic toxicity in animals. No systemic poisonings have been reported in humans. However, many workers having dermal contact with this acaricide, especially during the summer months, have experienced skin irritation and possibly sensitization in some cases.³³ Eye irritation has also occurred. For this reason, stringent measures should be taken to prevent inhalation or any skin or eye contamination by propargite.

Confirmation of Poisoning

There is no readily available method for detecting absorption of propargite.

Treatment

Treatment of contamination and ingestions should proceed essentially as outlined for haloaromatic substituted urea.

PYRETHROIDS

These modern synthetic insecticides are similar chemically to natural pyrethrins, but modified to increase stability in the natural environment. They are now widely used in agriculture, in homes and gardens, and for treatment of ectoparasitic disease.

Pyrethroids are formulated as emulsifiable concentrates, wettable powders, granules, and concentrates for ultra low volume application. They may be combined with additional pesticides (sometimes highly toxic) in the technical product or tank-mixed with other pesticides at the time of application. AASTAR (discontinued 1992), for instance, was a combination of flucythrinate and phorate. Phorate is a highly toxic organophosphate. Nix and Elimite are permethrin creams applied to control human ectoparasites.

Toxicology

Certain pyrethroids exhibit striking neurotoxicity in laboratory animals when administered by intravenous injection, and some are toxic by the oral route. However, systemic toxicity by inhalation and dermal absorption is low. Although limited absorption may account for the low toxicity of some pyrethroids, rapid biodegradation by mammalian liver enzymes (ester hydrolysis and oxidation) is probably the major factor responsible for this phenomenon.³⁴ Most pyrethroid metabolites are promptly excreted, at least in part, by the kidney.

The most severe, although more uncommon, toxicity is to the central nervous system. Seizures have been reported in severe cases of pyrethroid intoxication. Of 573 cases reviewed in China, there were 51 cases with disturbed consciousness and 34 cases with seizures. Of those, only 5 were from occupational exposure.³⁵ Seizures are more common with exposure to the more toxic cyano-pyrethroids, which include fenvalerate, flucythrinate, cypermethrin, deltapermethrin, and fluvalinate.³⁴ There are no reports in the literature of seizures in humans from exposure to permethrin.

Apart from central nervous system toxicity, some pyrethroids do cause distressing paresthesias when liquid or volatilized materials contact human skin. Again, these symptoms are more common with exposure to the pyrethroids whose structures include cyano-groups.³⁴ Sensations are described as stinging, burning, itching, and tingling, progressing to numbness.^{35, 36, 37} The skin of the face seems to be most commonly affected, but the face, hands, forearms, and neck are sometimes involved. Sweating, exposure to sun or heat, and applica-

tion of water enhance the disagreeable sensations. Sometimes the effect is noted within minutes of exposure, but a 1-2 hour delay in appearance of symptoms is more common.^{36,37} Sensations rarely persist more than 24 hours. Little or no inflammatory reaction is apparent where the paresthesia are reported; the effect is presumed to result from pyrethroid contact with sensory nerve endings in the skin. The paresthetic reaction is not allergic in nature, although sensitization and allergic responses have been reported as an independent phenomenon with pyrethroid exposure. Neither race, skin type, nor disposition to allergic disease affects the likelihood or severity of the reaction.

Persons treated with permethrin for lice or flea infestations sometimes experience itching and burning at the site of application, but this is chiefly an exacerbation of sensations caused by the parasites themselves, and is not typical of the paresthetic reaction described above.

Other signs and symptoms of toxicity include abnormal facial sensation, dizziness, salivation, headache, fatigue, vomiting, diarrhea, and irritability to sound and touch. In more severe cases, pulmonary edema and muscle fasciculations can develop.³⁵ Due to the inclusion of unique solvent ingredients, certain formulations of fluvalinate are corrosive to the eyes. Pyrethroids are not cholinesterase inhibitors. However, there have been some cases in which pyrethroid poisoning has been misdiagnosed as organophosphate poisoning, due to some of the similar presenting signs, and some patients have died from atropine toxicity.³⁵

Treatment

1. Skin decontamination. Wash skin promptly with soap and water as outlined in Chapter 2. If irritant or paresthetic effects occur, obtain treatment by a physician. Because volatilization of pyrethroids apparently accounts for paresthesia affecting the face, strenuous measures should be taken (ventilation, protective face mask and hood) to avoid vapor contact with the face and eyes. Vitamin E oil preparations (dL-alpha tocopheryl acetate) are uniquely effective in preventing and stopping the paresthetic reaction.^{37,38} They are safe for application to the skin under field conditions. Corn oil is somewhat effective, but possible side effects with continuing use make it less suitable. Vaseline is less effective than corn oil. Zinc oxide actually worsens the reaction.

2. Eye contamination. Some pyrethroid compounds can be very corrosive to the eyes. Extraordinary measures should be taken to avoid eye contamination. The eye should be treated immediately by prolonged flushing of the eye with copious amounts of clean water or saline. If irritation persists, obtain professional ophthalmologic care.

3. Gastrointestinal decontamination. If large amounts of pyrethroids, especially the cyano-pyrethroids, have been ingested and the patient is seen soon

after exposure, consider gastrointestinal decontamination as outlined in Chapter 2. Based on observations in laboratory animals³⁴ and humans,³⁵ large ingestions of allethrin, cismethrin, fluvalinate, fenvalerate, or deltamethrin would be the most likely to generate neurotoxic manifestations.

If only small amounts of pyrethroid have been ingested, or if treatment has been delayed, oral administration of activated charcoal and cathartic probably represents optimal management. Do not give cathartic if patient has diarrhea or an ileus.

4. Other treatments. Several drugs are effective in relieving the pyrethroid neurotoxic manifestations observed in deliberately poisoned laboratory animals, but none has been tested in human poisonings. Therefore, neither efficacy nor safety under these circumstances is known. Furthermore, moderate neurotoxic symptoms and signs are likely to resolve spontaneously if they do occur.

5. Seizures. Any seizures should be treated as outlined in Chapter 2.

SULFUR

Elemental sulfur is an acaricide and fungicide widely used on orchard, ornamental, vegetable, grain, and other crops. It is prepared as dust in various particle sizes and applied as such, or it may be formulated with various minerals to improve flowability, or applied as an aqueous emulsion or wettable powder.

Toxicology

Elemental sulfur is moderately irritating to the skin and is associated with occupationally related irritant dermatitis.³⁹ Airborne dust is irritating to the eyes and the respiratory tract. In hot sunny environments, there may be some oxidation of foliage-deposited sulfur to gaseous sulfur oxides, which are very irritating to the eyes and respiratory tract.

Ingested sulfur powder induces catharsis, and has been used medicinally (usually with molasses) for that purpose. Some hydrogen sulfide is formed in the large intestine and this may present a degree of toxic hazard. The characteristic smell of rotten eggs may aid in the diagnosis. An adult has survived ingestion of 200 grams.⁴⁰

Ingested colloidal sulfur is efficiently absorbed by the gut and is promptly excreted in the urine as inorganic sulfate.

Treatment

1. Skin decontamination. Wash skin with soap and water. Contamination of the eyes should be removed by prolonged flushing with clean saline or water. If eye irritation persists, obtain ophthalmologic care.

2. Gastrointestinal decontamination. Unless an extraordinary amount of sulfur (several grams) has been ingested shortly prior to treatment, there is probably no need for gastrointestinal decontamination. Adsorbability of sulfur on activated charcoal has not been tested.

The most serious consequence of sulfur ingestion is likely to be that of catharsis, resulting in dehydration and electrolyte depletion, particularly in children. If diarrhea is severe, oral or intravenous administration of glucose and/or electrolyte solutions may be appropriate.

References

1. Litovitz TL, Klein-Schwartz W, Oderda GM, and Schmitz BF. Clinical manifestations of toxicity in a series of 784 boric acid ingestions. *Am J Emerg Med* 1988;6(3):209-13.
2. Restuccio A, Mortensen ME, and Kelley MT. Fatal ingestion of boric acid in an adult. *Am J Emerg Med* 1992;10(6):545-7.
3. Ishii Y, Fujizuka N, Takahashi T, et al. A fatal case of acute boric acid poisoning. *Clin Toxicol* 1993;31(2):345-52.
4. Goldbloom RB and Goldbloom A. Boric acid poisoning. *J Pediatr* 1953; 43(6):631-43.
5. Wong LC, Heimbach MD, Truscott DR, and Duncan BD. Boric acid poisoning. *Can Med Assoc J* 1964;90:1018-23.
6. Ducey J and Williams DB. Transcutaneous absorption of boric acid. *J Pediatr* 1953;43(6):644-51.
7. Linden CH, Hall AH, Kulig KW, and Rumack BH. Acute ingestions of boric acid. *Clin Toxicol* 1986;24(4):269-79.
8. Hu X, Wegman DG, Eisen EA, et al. Dose related acute irritant symptom responses to occupational exposure to sodium borate dusts. *Br J Ind Med* 1992;49:706-13.
9. Garabrant DH, Bernstein L, Peters JM, et al. Respiratory effects of borax dust. *Br J Ind Med* 1985;42:831-7.
10. Schillinger BM, Berstein M, Goldbert LA, and Shalita AR. Boric acid poisoning. *J Am Acad Dermatol* 1982;7(5):667-73.
11. O'Sullivan K and Taylor M. Chronic boric acid poisoning in infants. *Arch Dis Child* 1983;58:737-49.
12. Segar WE. Peritoneal dialysis in the treatment of boric acid poisoning. *New Engl J Med*, 1960;262(16):798-800.
13. Folland DS, Kimbrough RD, Cline RE, et al. Acute hemorrhagic cystitis. *JAMA* 1978;239(11):1052-5.
14. Arima T, Morooka H, Tanigawa T, et al. Methemoglobinemia induced by chlorphenamide. *Acta Med Okayama* 1976;30:57-60.

15. Ravindran M. Toxic encephalopathy from chlorobenzilate poisoning: Report of a case. *Clin Electroencephalogr* 1978;9(4):170-2.
16. Veltri JC, Osimitz TG, Bradford DC, et al. Retrospective analysis of calls to poison control centers resulting from exposure to the insect repellent N, N-diethyltoluamide (DEET) from 1985-1989. *Clin Toxicol* 1994;32:1.
17. Tenebein M. Severe toxic reactions and death following ingestion of diethyltoluamide-containing insect repellents. *JAMA* 1987;258:1509.
18. Maibach HI and Johnson HL. Contact urticaria syndrome. *Arch Dermatol* 1975;111:726.
19. Wantke F, Focke M, Hemmer W, et al. Generalized urticaria induced by a diethyltoluamide-containing insect repellent in a child. *Contact Dermatitis* 1996;35(3):186.
20. Reuveni H. and Yagupsky P. Diethyltoluamide-containing insect repellent: Adverse effects in worldwide use. *Arch Dermatol* 1982;118:582.
21. Stinecipher J and Shaw J. Percutaneous permeation of N,N-diethyl-m-toluamide (DEET) from commercial mosquito repellents and the effect of solvent. *J Toxicol Environ Health* 1997;52:119.
22. Lipscomb JW, Kramer JE, and Leikin JB. Seizure following brief exposure to the insect repellent N,N-diethyl-m-toluamide. *Ann Emerg Med* 1992;21(3):315-17.
23. Zadikoff CM. Toxic encephalopathy associated with use of insect repellent. *J Pediatr* 1979;95:140-2.
24. Pronczuk de Garbino J and Laborda A. Toxicity of an insect repellent: N,N- diethyltoluamide. *Vet Hum Toxicol* 1983;25:422-3.
25. Hebert AA and Carlton S. Getting bugs to bug off: A review of insect repellents. *Contemp Pediatr* 1998;15:85-95.
26. Yolken R, Konecny P, and McCarthy P. Acute fluoride poisoning. *Pediatrics* 1976;58(1):90-3.
27. Heifetz SB and Horowitz HS. Amounts of fluoride in self-administered dental products: Safety considerations for children. *Pediatrics* 1986;77(6):876-82.
28. Gessner BD, Beler M, Middaugh JP, and Whitford GM. Acute fluoride poisoning from a public water system. *New Engl J Med* 1994;330(2):95-9.
29. Swanson L, Filandrinos DT, Shevlin JM, and Willett JR. Death from accidental ingestion of an ammonium and sodium bifluoride glass etching compound. *Vet Hum Toxicol* 1993; 35(4):351.
30. Harchelroad F and Goetz C. Systemic fluoride intoxication with leukocytosis and pyrexia. *Vet Hum Toxicol* 1993;35(4):351.
31. Spak CJ, Sjöstedt S, Eleborg L, et al. Tissue response of gastric mucosa after ingestion of fluoride. *Br Med J* 1989;298:1686-7.
32. Baltazar RD, Mower MM, Reider R, et al. Acute fluoride poisoning leading to fatal hyperkalemia. *Chest* 1980;78:660.
33. Saunders LD, Ames RG, Knaak JB, et al. Outbreak of omite-cr-induced dermatitis among orange pickers in Tulare County, California. *J Occup Med* 1987;29:409-13.
34. Dorman DC and Beasley VR. Neurotoxicology of pyrethrin and the pyrethroid insecticides. *Vet Hum Toxicol* 1991;33(3):238-43.
35. He F, Wang S, Lui L, et al. Clinical manifestations and diagnosis of acute pyrethroid poisoning. *Arch Toxicol* 1989;63:54-8.
36. Tucker SB and Flannigan SA. Cutaneous effects from occupational exposure to fenvalerate. *Arch Toxicol* 1983;54:195-202.
37. Flannigan SA, Tucker SB, Key MM, et al. Synthetic pyrethroid insecticides: A dermatological evaluation. *Br J Ind Med* 1985;42:363-72.

38. Tucker SB, Flannigan SA, and Ross CE. Inhibitions of cutaneous paresthesia resulting from synthetic pyrethroid exposure. *Int J Dermatol* 1984;10:686-9.
39. O'Malley MA. Skin reactions to pesticides. *Occup Med* 1997;12:327-45.
40. Schwartz SM, Carroll HM, and Scharschmidt LA. Sublimed (inorganic) sulfur ingestion - A cause of life-threatening metabolic acidosis with a high anion gap. *Arch Intern Med* 1986;146:1437-8.