Inorganic Mercury

TEACH Chemical Summary

Inorganic mercury is one of three forms of mercury listed in TEACH. In addition to this Chemical Summary, there are separate Chemical Summaries for organic mercury (e.g., methylmercury) and for elemental mercury.

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

Mercury in elemental form is a silver-colored metal that exists as a thick liquid at room temperature, familiar to most people as the silver liquid inside mercury thermometers. Mercury can chemically combine with other elements to form organic (carbon-containing) and inorganic (not containing carbon) compounds. Mercury is a naturally-occurring metal that is used in man-made products and processes, and is emitted into air from industrial sources (1-3). Human exposure to mercury occurs from a variety of sources, e.g., breathing mercury-containing air, using commercial products that contain mercury, and ingesting some types of fish that contain methylmercury (1, 2, 4, 5). The U.S. EPA provides a Web site with information about mercury exposure and effects, with a portal at www.epa.gov/mercury (6).

There are three major types of mercury, each of which is covered in a separate TEACH Chemical Summary: 1) elemental mercury, found in thermometers, fluorescent bulbs, dental amalgam fillings, and other sources; 2) organic mercury, predominantly methylmercury, found in foods such as fish, and ethylmercury found in some vaccine preservatives and some antiseptics; and 3) non-elemental forms of inorganic mercury, found primarily in batteries, some disinfectants, and some health remedies and creams (1, 2, 5). This Chemical Summary focuses on non-elemental inorganic mercury; additional information on elemental and organic mercury is available in separate Chemical Summaries on this U.S. EPA TEACH Web site.

Inorganic mercury describes a category of mercury compounds that includes mercuric chloride, mercuric acetate, mercuric sulfide, and other compounds. Of the inorganic mercury compounds, mercuric chloride is more common than other compounds. Mercuric chloride is a white powder that is soluble in water (1-3, 5). Exposure of children to inorganic mercury above levels of concern is uncommon, and most likely to occur following ingestion of items containing inorganic mercury, such as some batteries; or use of some homeopathic remedies or skin bleaching creams (1, 3, 7-11).

Mercuric chloride exposure can be toxic to the kidney, stomach, and intestines; and can lead to increased blood pressure (1, 12). Experimental animal studies have shown embryotoxic effects, including increased rates of miscarriage and stillbirths, following mercuric acetate exposure (13-15) or mercuric chloride exposure (16-19) during pregnancy. Autoimmune kidney damage has also been reported in adult rats following mercuric chloride exposure (1).

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

Exposure Media	Relative Potential for Children's Exposure[2,3]	Basis[4]
Commercially-Available Personal Care Products	Medium	Inorganic mercury can be found as a constituent in some imported cosmetic skin-bleaching creams and herbal remedies. Mercuric chloride is also found in some batteries.
Medical/Medicinal and Home Remedies	Lower	Inorganic mercury may found at elevated levels in some medicinal and home remedies. *See the Organic Mercury Chemical Summary for information about ethylmercury from some vaccine uses.*
Indoor Air	Lower	Inorganic mercury is not generally found at elevated levels in indoor air. Indoor air may contain higher levels of inorganic mercury, e.g., in homes of industrial workers who work in chlor-alkali plants after workers wear clothes home from the workplace that are contaminated with inorganic mercury. *See the Elemental Mercury Chemical Summary for information about mercury exposure in indoor air from elemental mercury spills, such as from mercury-containing thermometer or equipment breakage.*
Diet	Lower	Inorganic mercury is not generally found in foods. *See the Organic Mercury Chemical Summary for information about methylmercury exposure from diet, particularly eating fish.*
Ambient Air	Lower	Inorganic mercury is not generally found at elevated levels in ambient air.
Drinking Water	Lower	Inorganic mercury is not generally found at elevated levels in drinking water.
Sediment	Lower	Inorganic mercury is not generally found at elevated levels in sediment.
Soil	Lower	Inorganic mercury is not generally found at elevated levels in soil.
Surface Water	Lower	Inorganic mercury is not generally found at elevated levels in surface water.

[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 the 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., 1-5) including studies listed in the TEACH Database (http://www.epa.gov/teach).

III. TOXICITY SUMMARY[5, 6]

Mercury is a neurotoxicant, and may affect many areas of the brain (1, 2, 12). Different forms of mercury may not all have neurotoxic effects listed here, and many neurotoxic effects of mercury exposure have been attributed to methylmercury exposure (see TEACH Organic Mercury Chemical Summary). Reported neurotoxic symptoms of mercury exposure include poor performance on neurobehavioral tests, of attention, fine motor function, language, visual-spatial abilities (e.g., drawing), and verbal memory (1, 2, 12). Exposure to mercury during pregnancy and development may impact neurological and cognitive development of children (see TEACH Organic Mercury Chemical Summary) (20, 21).

Children and adults exposed to mercury, including inorganic mercury, have been reported to develop a disorder called acrodynia, or "pink disease" (1, 12). Symptoms include leg cramps; irritability; and redness and peeling of the skin of hands, nose, and soles of the feet. Itching, fever, sweating, salivating, rashes (including "baboon syndrome" rashes in the buttocks, anal, and genital regions), sleeplessness, and/or weakness have also been reported (1). Additional reported effects of inorganic mercury exposure in children and adults include kidney damage and digestive tract problems including diarrhea, nausea, and ulcers (1, 12). Increased blood pressure and decreased heart rate variability in children exposed to mercury has been reported (1, 12, 22-24). Neurological effects including twitching, tics (uncontrollable muscle movements), and impaired gait have been reported in adults and children following exposure to mercuric chloride (1, 9, 12, 25). There are limited reports of death in adults following ingestion of mercuric chloride at doses of 10-42 mg mercury per kg body weight with cardiovascular failure, gastrointestinal damage, and acute renal failure (10).

In experimental animal studies, mercuric acetate or mercuric chloride exposure during development led to embryotoxicity (increased fetal deaths, and increased occurrence of fetal abnormalities such as retarded growth and exencephaly, or exposed brain tissue) in hamsters and mice (13-19, 26). Following mercuric chloride exposure, neonatal rats exhibited altered rates of organ growth for several organs (e.g., liver, brain, heart), and altered levels of several neurotransmitters in the brain (27); in adult rats exposure resulted in hair loss, weight loss, and immune-mediated kidney damage in adult rats (1). Following acute exposure to mercuric chloride (>0.46 mg/kg/day), adult rats experienced acute renal failure attributed to tubular and glomerular pathology (12).

Carcinogenicity Weight-of-Evidence Classification[7]: Mercuric chloride was classified by U.S. EPA in 1994 as a possible human carcinogen based upon an absence of data in humans and limited evidence of carcinogenicity in rats (observed renal tubular cell tumors in adult rats) (1) (www.epa.gov/iris/subst/0692.htm, II.A.1). The World Health Organization International Agency for Research on Cancer (IARC) in 1997 classified inorganic mercury compounds as Group 3, "not classifiable as to their carcinogenicity in humans," with insufficient evidence for carcinogenicity in humans, and limited evidence for carcinogenicity of mercuric chloride in experimental animals (http://monographs.iarc.fr/ENG/Monographs/vol58/volume58.pdf).

[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*

Studies that measured total mercury, without distinguishing forms of mercury:

- Total mercury has been measured in many types of food (1, 4, 28-30), including infant and toddler foods (26) and children's diet (28). Another study estimated mercury exposure of children from diet in Canada (29). The largest proportion of mercury in diet was attributed to the presence of methylmercury in fish (see Organic Mercury Chemical Summary) (1).
- Total mercury concentrations have been measured in umbilical cord blood (30-36), placenta (31, 32), and fetal hair (32). One study in Tennessee measured total mercury in fetal blood, placenta, and maternal blood for over 650 pregnancies, and reported significant correlations between mercury concentrations in maternal blood and in fetal blood (32). In a study of pregnant women in Iowa, increasing blood total mercury concentrations were correlated with the incidence of previous stillbirths, and separately with a history of having children with birth defects (30).
- Total mercury concentrations have also been measured in blood, urine, fingernails, and hair of children (34, 37-59), as well as in breast milk (31, 34, 60-68). Also, as part of a large national study (National Health and Nutrition Examination Survey, or NHANES; 1999-2002), total mercury concentrations were measured in blood of children 1-5 years old, and in blood and urine of women 16-49 years old were measured (69). Results indicated that 5.7% of women 16-49 years old had mean total mercury concentrations in blood higher than 5.8 μg/L (blood mercury levels below 5.8 μg/L, the U.S. EPA reference blood level, were estimated to be without appreciable harm) (52).
- Possible effects of mercury exposure on pregnancy outcome have been studied. One study found a correlation between increased incidence of miscarriage and total mercury concentrations in well water (70). In a study of pregnant women in Iowa, increasing blood total mercury concentrations were correlated with the incidence of previous stillbirths, and separately with a history of having children with birth defects (71).
- Longitudinal studies of possible neurodevelopmental effects of mercury exposure have been performed, measuring total mercury concentrations in hair and blood of pregnant women and their children over time (1, 12). In studies from the Faroe Islands and elsewhere, poorer performance on neuropsychological tests in children was associated with higher concentrations of mercury in maternal hair during pregnancy or in cord blood (33, 53, 72-77). Similar correlations were found in another study in New Zealand (78). In contrast, other studies in the Seychelle Islands found few correlations between mercury concentrations in maternal hair and neurological impairments in children (68, 79-88). Mercury exposures in these studies were largely attributed to methylmercury exposure from the consumption of fish in the diet (72-74, 79-92). These large studies, in conjunction with other data, have been carefully evaluated and analyzed by the National Research Council and the U.S. EPA, and provide the basis for derivation of the current U.S. EPA oral reference dose (RfD) for methylmercury (91, 92).

Supporting references and summaries are provided in the TEACH database at *http://www.epa.gov/teach/*.

- Children's total mercury blood concentrations were significantly associated with other health effects, including increased N-acetyl-beta-D-glucosaminidase (a measure of kidney function) and decreased serum prolactin (indicating a shift in neurobiochemical metabolism) (58). Total mercury concentrations in blood and in hair were significantly associated with decreased logical and spatial abilities (56). There were no significant impairments in cognitive testing of children amalgam (mercury-containing) dental fillings, as compared to children with composite (mercury-free) fillings (93, 94). More information about mercury exposure from dental amalgam use is summarized in the TEACH Elemental Mercury Chemical Summary.
- Possible associations between autism spectrum disorders (ASD) and environmental exposure to mercury have been explored. Increased incidence of ASD was associated with mercury air concentration at the census tract level (95), and with total reported environmental mercury releases (96). One study reported no significant difference in blood concentrations of total mercury between children with ASD, and children without ASD (97). More information about mercury exposure from vaccines is summarized in the TEACH Organic Mercury Chemical Summary.
- Some adverse effects on vision (e.g., reduced contrast sensitivity, with difficulties sensing shades of gray) in children were significantly associated with increased total mercury concentrations in blood (98). In another study, there was no association between contrast sensitivity in 7-year-old children, and their cord blood total mercury concentrations at birth (99).
- Increases in blood pressure and decreases in heart rate variability in 7-year-old children were associated with increasing total mercury concentrations in cord blood at their birth (23). A follow-up of those children at 14 years of age revealed that there was no longer a significant increase in blood pressure associated with cord blood mercury concentrations, though a significant association with decreases in heart rate variability remained (24).
- Exploring possible thyroid effects, one study reported no significant association between cord blood total mercury concentrations and infant thyroid hormone concentrations (35). Another large study of children found no correlation between blood total mercury levels and blood thyroid hormone levels (100).

Studies that measured inorganic mercury:

- Some studies specifically measured concentrations of inorganic mercury in blood and urine from pregnant women and their fetuses (4, 34, 43, 46, 101-103). One study reported that the majority of mercury in the blood of pregnant women was methylmercury, and a smaller proportion was inorganic mercury (43). Inorganic mercury can cross the placenta (101), and has been measured in cord blood (34, 46, 101, 102), and placenta (46, 101-103). Inorganic mercury has been detected in human fetal liver, but not brain (103).
- Inorganic mercury concentrations have been measured in children's blood and urine (4, 7, 10, 39, 41, 43-45, 69) and has been detected in breast milk (34, 66, 104).
- Mothers with higher inorganic mercury blood concentrations (in the highest 5% of concentrations measured in this particular study) were nine times more likely to have a child with a neural tube defect (105).

- Increasing maternal blood inorganic mercury concentrations were significantly associated with decreasing maternal blood concentrations of the thyroid hormone, T3; there was no significant association with fetal thyroid hormone concentrations (35).
- Children are most likely to be exposed to high levels of inorganic mercury via ingestion. Reported acute exposures of children to inorganic mercury included ingestion of batteries (7) and use of some homeopathic medicines (8, 9, 11). Dermal exposure of children from use of some imported skin bleaching creams has been reported, though currently the sale of skin bleaching creams containing mercury is very uncommon in the U.S. following the U.S. FDA ruling that such creams are not considered generally safe and effective (see U.S. Federal Regulatory Information) (10).
- There are currently few published studies that specifically address health effects in children following exposure to inorganic mercury. Most studies pertaining to mercury exposures and effects in children have measured total mercury or methylmercury levels (see each TEACH Chemical Summary for Elemental Mercury and Organic Mercury for additional information).
- Acrodynia (also called “pink disease”) is a syndrome that includes a range of symptoms, and has been associated with exposure to mercury, including inorganic mercury (1, 12). Associated symptoms include leg cramps, irritability, redness and peeling of skin on hands, nose, and soles of the feet. Itching, fever, sweating, salivating, rashes, sleeplessness, and/or weakness have also been present. Acrodynia was confirmed in Iraq following an incident where many families were exposed to mercury-contaminated grain between 1955 and 1972 (see the TEACH Organic Mercury Chemical Summary) (1, 12). Acrodynia has also been observed in children, teens, and adults following use of skin bleaching creams (1, 12).
- Neurological effects in children have been reported following exposure to mercuric chloride or mercuric sulfide (1, 9, 25). Symptoms included neurological tics (uncontrollable muscle movements), impaired gait, and convulsions (1, 9, 25).
- There have been a number of case studies of inorganic mercury exposure involving children. Some herbal remedies may contain inorganic mercury, and use of these remedies has resulted in adverse health effects in children. Abnormal heart rhythms, increased heart rate, and elevated blood pressure were observed in children exposed to mercuric chloride in older medicinal treatments for worms or for teething discomfort prior to the 1960's; these treatments are no longer in use (1). An immune-mediated red, itchy skin rash was reported in a 5-year-old child following exposure to a homeopathic medicine that contained inorganic mercury (8); the rash was similar to a characteristic rash called “baboon syndrome” which is an acute rash in the buttocks, genital, and anal regions sometimes seen after exposure to mercury or other compounds, including some antibiotics. In another study, motor tics (uncontrollable movements) including eye blinking, head turning, and shoulder shrugging in a boy were reported following exposure to inorganic mercury from ingestion of an herbal remedy in Hong Kong (9).
- No observable health effects were noted in two other reports of children with increased inorganic mercury concentrations in urine as high as 200 μg/L (7, 10). Note that mercury concentrations of concern in blood and urine can be quite different (see the third bullet in this section for information about blood mercury concentrations).

B. *EXPERIMENTAL ANIMAL EXPOSURE AND EFFECTS*

Experimental animal studies summarized here involved inorganic mercury exposure.

- The accumulation, tissue distribution, and excretion of inorganic mercury have been studied in pregnant or developing hamsters (106-108), mice (109-111), and rats (112-115). These studies used protocols of maternal prenatal (106, 107, 112, 114), lactational (107-109, 111, 112, 114), or early life exposure (109, 110, 113, 115). Inorganic mercury accumulated in fetal liver (106), and in liver, brain, kidney, and plasma of neonatal or young offspring (110, 114). One study compared tissue distribution of mercuric chloride and ethlymercury injection of nursing pups, and found significant differences in mercury tissue distribution between the two forms of mercury (i.e., more mercury in kidney and liver with mercuric chloride exposure, and more mercury in blood and brain with thimerosal exposure) (115).
- Inorganic mercury has been shown to cross the placenta in hamsters and rats (106, 107, 112).
- Inorganic mercury was shown to be secreted in breast milk (104, 107, 110-112), and absorbed from breast milk by nursing pups (111). Neonatal rats demonstrated greater absorption of inorganic mercury in the gastrointestinal tract than weanling or adult rats (113).
- Inorganic mercury has been detected in fetal tissues following methylmercury exposure in hamsters (51, 59). Following methylmercury exposure, inorganic mercury was detected in fetal liver and brain, suggesting that methylmercury may be processed in the body to form inorganic mercury (106, 107).
- Possible effects of exposure to inorganic mercury on germ cells have been studied. Mercuric chloride exposure had no observable adverse effects on oocytes from exposed hamsters (116) or mice (117). Exposure of adult male or female mice to mercuric chloride prior to mating had reduced numbers of live pups at birth (16, 118). In adult male mice exposed to mercuric chloride with a single intraperitoneal injection, there was decreased fertility and changes in sperm development (119).
- Embryotoxic effects following maternal exposure to mercuric acetate during pregnancy were reported in hamsters (13-15). Increased resorptions (fetal deaths) and increased abnormalities (i.e., retarded growth, exencephaly or exposed brain tissue, and fused ribs) in offspring were significantly increased (13-15). The sensitivity of embryos to mercuric acetate toxicity varied between strains of hamsters with differing genetic backgrounds (13). Routes of administration of mercuric acetate were compared in one study with hamsters, and the intraperitoneal injection route demonstrated embryotoxic effects at lower doses than other injection sites, or oral exposure (14). Embryotoxic effects of mercuric acetate were negated when zinc was co-administered during pregnancy (15).
- Following mercuric chloride exposure during pregnancy, embryotoxic effects were observed in mice and rats. There was a significant reduction in the percentage of live pups per litter following mercuric chloride exposure via maternal subcutaneous injection (13, 16, 18) or intravenous injection (17, 19). Maternal exposure to mercuric chloride aerosol via inhalation during pregnancy led to increased incidence of delayed bone ossification in offspring, and increased numbers of dead fetuses (26). Hamsters were more sensitive to embryotoxic effects of mercuric chloride exposure than mice (17).
- Immune system effects were observed in offspring following maternal exposure to mercuric chloride during pregnancy via drinking water (100). As adults, male offspring had significantly increased production of some cytokines (e.g., gamma interferon and Interleukin 4) while female offspring had decreased production of these cytokines (120).

- Exposure of neonatal rats to mercuric chloride by subcutaneous injection resulted in changes in growth of brain, heart, kidney, and liver that differed for each type of tissue(25, 121), and stabilized toward normal growth over time (27); growth of some organs increased and some decreased. Levels of ornithine decarboxylase activity, norepinephrine, dopamine, and other neurochemicals were also altered (increased or decreased) in specific areas of the brain following this exposure regimen (27). The metal-binding chelator 2,3-dimercapto-1-propanol (BAL) was not effective in alleviating symptoms of toxicity in one study (121).

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.

Information About Reducing or Preventing Exposures

- Much information on children's health following inorganic mercury exposure comes from information published prior to the 1960s (1, 4). The TEACH Database contains scientific articles published in 1972 or later, and therefore does not contain these publications; these articles are summarized elsewhere (1, 4, 12). Many of these earlier studies reported effects of exposure to mercuric chloride in infants and children from the use of some household products, such as diaper creams and laxatives, which, in the past, contained significant amounts of mercuric chloride; these products no longer contain mercury compounds (1, 4).
- Some medications, including over-the-counter medications, contain small amounts of mercury as a preservative, or in solutions to be used as antiseptics (such as mercurochrome). The U.S. FDA maintains a list of medications that contain mercury (122).
- Herbal remedies may contain inorganic mercury, though reported cases of such exposures were the result of use of herbal remedies from non-U.S. sources (1, 2, 9). Some traditional Chinese and Hispanic remedies for stomach disorders (e.g. herbal balls) may contain inorganic mercury (2).
- Skin-bleaching creams that contain ammoniated mercuric chloride or mercuric iodide can result in mercury exposure (1). The U.S. FDA ruled that these skin-bleaching creams are not generally safe and effective, and consequently sale of these creams in the U.S. has been greatly reduced or stopped (see U.S. Regulatory Information in this Chemical Summary).
- Mercury exposure can occur as a consequence of spills from broken thermometers, gauges, or other commercially-available items that contain mercury (1, 2, 4, 123); for more details see the TEACH Elemental Mercury Chemical Summary. Mercury exposure can also occur from eating fish, and some types of fish contain more mercury than others (1, 2, 4, 122-124); for more details see the TEACH Organic Mercury Chemical Summary.

Other Exposure Information

- Mercury concentrations in hair have been measured as part of the National Human Exposure Assessment Survey (NHEXAS), designed to evaluate human exposure to several chemicals on a regional scale in the U.S.; the first phase of the study was completed in 1998 (125). Hair mercury concentrations for 182 people, including children, living in the Midwest have been measured as part of this survey (39).
- Concentrations of mercury in blood and urine of women 16-49 years old and children 1-5 years old were measured from 1999-2002 as part of the ongoing National Health and Nutrition Examination Survey (NHANES) list of chemicals (69). This comprehensive survey is administered annually by the U.S. Centers for Disease Control and Prevention National Center for Health Statistics (69).
- The U.S. EPA used 1999 emissions data for mercury compounds for all 50 states to report county-level emissions, modeled ambient air concentration estimates, modeled human inhalation exposure, and estimated risk (126).

Other Information Resources

- The U.S. EPA provides a Web site with a broad array of information resources pertaining to mercury exposure and health effects (123). Detailed compilations and analyses of information pertaining to exposure and health effects of inorganic mercury are presented in the Toxicological Profile for Mercury (1). A Hazard Summary for Mercury Compounds is also available from the U.S. EPA, which summarizes information derived from several sources (127).
- A detailed health risk assessment for mercury and mercury compounds is available as a component of the U.S. EPA "Mercury Study Report to Congress" which contains detailed information about mercury emissions, health and environmental implications of those emissions, and emission control technologies (128).
- Mercury and mercury compounds are listed as number 3 on the 2005 Priority List of Hazardous Substances for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) section 104 (i), as amended by the Superfund Amendments and Reauthorization Act (SARA). This is a list, in the order of priority of concern, of substances most commonly found at sites listed on the National Priorities list (NPL); there are currently 275 substances on this list (129). Mercury had been found in at least 714 of 1,467 current or former NPL sites (1).
- Consult the U.S. EPA "Child-Specific Exposure Factors Handbook" (EPA-600-P-00-002B) for factors to assess children's dermal absorption and inhalation rates (129). An updated External Draft of the 2006 version of this handbook is available (130).

VI. TOXICITY REFERENCE VALUES

Mercuric Chloride

A. Oral/Ingestion

U.S. EPA RfD for Chronic Oral Exposure: 3E-4 (or 0.0003) mg/kg-day; based on autoimmune glomerularnephritis in adult Brown Norway rats (http://www.epa.gov/iris/subst/0692.htm, I.A.1) (131). Last Workgroup Verification Date 11/16/88.

U.S. EPA Drinking Water Advisories (10 kg child or 22 lb. child): 1 day = 0.002 mg/L, 10 day = 0.002 mg/L (http://www.epa.gov/ost/drinking/standards/dwstandards.pdf) (132). Last revised 5/1/95.

U.S. EPA Maximum Contaminant Level (MCL) for Drinking Water: 0.002 mg/L, based on kidney damage in adults (http://www.epa.gov/safewater/mcl.html#mcls) (133). Last revised 7/02.

U.S. EPA Maximum Contaminant Level Goal (MCLG): 0.002 mg/L, based on kidney damage (http://www.epa.gov/safewater/mcl.html#mcls) (133). Last revised 7/02.

B. Inhalation

U.S. ATSDR Minimal Risk Level (MRL): 0.007 mg/kg/day (oral acute exposure, renal effects); 0.002 (oral intermediate exposure, renal effects) (http://www.atsdr.cdc.gov/mrls/index.html) (134). Last revised 3/99.

VII. U.S. FEDERAL REGULATORY INFORMATION

- The U.S. FDA ruled that skin bleaching creams containing inorganic mercury (ammoniated mercuric chloride or mercuric iodide) were not generally recognized as safe and effective, and subsequent sales of the products in the U.S. were eventually stopped. However, foreign skin-bleaching products containing inorganic mercury have been found for sale in the U.S., and their use has been reported (1).
- Mercurochrome (merbromin) is an antiseptic solution that contains small amounts of mercury (2% mercury). The U.S. FDA issued a final rule on April 22, 1998 (63 FR 19799) that merbromin (and other mercury active ingredients) as not generally recognized as safe and effective as an active ingredient for over-the-counter (OTC) first aid antiseptic and antimicrobial diaper rash uses. Also, the FDA ruled that products containing these ingredients for these uses could no longer be initially introduced or initially delivered for introduction into interstate commerce after October 19, 1998. This FDA ruling reduced or eliminated marketing and sales of these products at the retail level in the U.S., though mercurochrome is readily available in other countries and still may be in use in the U.S. (135).
- Mercury is one of 188 hazardous air pollutants (HAPs) listed under section 112(b) of the 1990 Clean Air Act Amendments and is regulated from more than 170 industrial source categories (136).

- The U.S. EPA requires reporting of quantities of certain chemicals that exceed a defined reportable quantity, and that quantity varies for different chemicals (137). Under the Emergency Planning and Community Right-to-Know Act (EPCRA) Section 313 "Toxic Chemicals," mercury is classified as a persistent, bioaccumulative and toxic compound (PBT) and as such, quantities of mercury greater than 10 pounds manufactured or processed, or otherwise used, is required (137, 138). Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), reporting releases of any quantity exceeding 1 pound is required (137).
- For a comprehensive list of mercury regulations and standards, go to *http://www.epa.gov/mercury/regs.htm*.

VIII. BACKGROUND ON CHEMICAL

A. CAS Number: 7487-94-7 (mercuric chloride); 7546-30-7 (mercurous chloride); 1600-27-7 (mercuric acetate); 1344-48-5 (mercuric sulfide); 21908-53-2 (mercuric oxide).

B. Physicochemical Properties: Mercuric chloride is a white powder that is soluble in water. Mercuric acetate is a white or off-white odorless powder. Mercuric sulfide is a black or red powder (differing in color depending on the process used to make the powder). Go to the National Library of Medicine ChemID Web site (*http://chem.sis.nlm.nih.gov/chemidplus*) and search for mercuric chloride, mercuric acetate, or mercuric sulfide.

C. Production: There are several inorganic salts of mercury, the most common of which is mercuric chloride (1, 2, 5). Examples of other inorganic mercury compounds include mercuric sulfate, mercuric sulfide, and mercuric oxide. Inorganic mercury occurs naturally in the environment, and is also released as a consequence of human activities (1-3). Inorganic mercury is mined and processed to generate elemental mercury. Most of the mercury found in the environment is elemental and inorganic mercury that was released into air from mercury mining processes, emissions of coal-fired power plants, emissions from some solid waste incinerators, and other industrial sources (1-3). U.S. production of total mercury in 1995 was estimated to be 158 tons, while world production of total mercury in 1995 was estimated to be 5,500 tons (3). A recent analysis estimated that U.S. production of total mercury from secondary facilities is approximately 430 tons/year (139).

D. Uses: Inorganic mercury can be found in some skin-lightening creams, some homeopathic medicines, and some batteries (1, 2, 5). Mercuric chloride may also be used as a topical antiseptic or disinfectant (1). Mercurous chloride was widely used in laxatives, worming medications, and teething powders over 40 years ago, but is no longer used in these products (1, 2). Mercuric sulfide as cinnabar ore is orange in color, and is mined and then processed to form liquid elemental mercury (1, 2). Mercuric sulfide and mercuric oxide are red (or in some preparations, black) in color, and are used for pigment in some paints and tattoo dyes (1, 2). In 2004, the total amount of reported releases and disposals of mercury compounds in the U.S. was over 4.7 million pounds (122); total releases are likely to be greater than this estimate because not all sources of mercury compound releases are required to report (1, 129).

E. Environmental Fate: Mercury is released in the environment as a result of both natural and human activities, and persists over time, though the form in which it exists changes over time (1-3). Metallic mercury enters the air from mining ore deposits, burning coal and waste, and from manufacturing plants (1-3). It enters the water or soil from erosion of natural deposits, discharge from refineries and factories, and runoffs from landfills and crop lands. Mercury emissions are transported through ambient air, and deposited to water and land where humans and wildlife can be exposed. Concentrations of mercury in ambient air are usually low and of little direct concern (1, 2, 4). Once mercury enters water, either through air deposition or soil runoff, microorganisms such as bacteria transform inorganic mercury in the environment to methylmercury, which can then bioaccumulate in fish and animal tissue (1, 2, 4). Higher levels of methylmercury are found in some types of fish (e.g., shark, swordfish, and tile fish) than others (see TEACH Organic Mercury Chemical Summary) (122-124).

F. Synonyms and Trade Names: mercuric chloride, mercuric acetate, mercuric sulfide, mercuric oxide, mercury bichloride, corrosive sublimate, mercuric (II) chloride, mercury perchloride, mercurous (I) chloride, and others. For a more complete list, go to *http://chem.sis.nlm.nih.gov/chemidplus/* and search for each compound individually.

Additional information on inorganic mercury is available in the TEACH Database for Inorganic Mercury, and at the following Web sites:

www.epa.gov/glnpo/sediments.html
www.epa.gov/ost/fish/mercurydata.html
www.epa.gov/mercury

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