

# MERCURY

Hg

EHS 201: Health Effects of Environmental Contaminants

10/18/05

Allison Bendush

# Mercury Presentation Outline

- Background
- Exposures
- Toxicology
- Health Effects
- Risk Assessment
- Regulations
- Alternatives & Solutions

*BACKGROUND:*

# Why Hg?

- Highly prevalent and persistent in environment
- Historical significance – Minamata Bay
- High-level occupational exposures documented
- Chronic low-level environmental exposures world wide
- Consumption of fish leads to exposure (Me-Hg)
- Concern over Hg regulation today – Fossil-fuel power plants, Clear Skies Act

## BACKGROUND:

# Minamata Bay

- Minamata = small factory town in southern Japan
- From 1938 to 1968, the Chisso Corporation (petrochemicals & plastics) dumped an estimated 27 tons of Hg compounds (mercuric chloride) into Minamata Bay
- In the 1950's methylmercury poisonings are reported in thousands, 397 officially reported dead
- Exposure through consumption of contaminated fish
- Children born to exposed women had severe nerve damage
- Became known as "Minamata Disease"



*BACKGROUND:*

## More recently...

- In 1997 a Dartmouth College scientist died of Hg poisoning 10 months after a few drops of dimethylmercury seeped through her latex gloves
- Tests showed 80x's the lethal dose of Hg in her blood

*BACKGROUND:*

# Forms

- Metallic (elemental)
- Inorganic
- Organic

*BACKGROUND:*

# Metallic (Elemental) Hg

- Pure form, not combined with other elements
- Shiny, silver-white metal
- Liquid at room temperature
- Thermometers, electrical switches
- Some evaporates to form Hg vapors

*BACKGROUND:*

# Inorganic Hg

- Occurs when Hg combines with Cl, S, or O
- AKA Hg salts
- Most are white powders or crystals (except mercuric sulfide)
- Mercuric chloride & mercurous chloride were widely used in medicinal products of the past (antiseptics, disinfectants, laxatives, teething powders, etc.)



Mercuric chloride

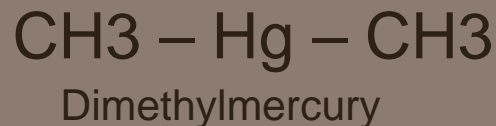
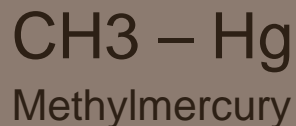


Mercurous chloride

*BACKGROUND:*

# Organic Hg

- Occurs when Hg combines with C
- Large number but most common is methylmercury (AKA monomethylmercury)
- Phenylmercury used in some products in the past
- Dimethylmercury is the only organic Hg ever to have been identified at hazardous waste sites – very harmful to humans and animals



## EXPOSURES:

# Environment

- Natural degassing of earth's crust (major source of Hg as vapor in atmosphere)
- Difficult to assess human Hg contributions
  - 80% released into air (fossil fuel combustion, mining, smelting, solid waste incineration)
  - 15% released into soil (fertilizers, solid waste → batteries, electrical switches, thermometers)
  - 5% released into water (industrial waste water)
- Current atmospheric Hg levels 3-6 times higher than pre-industrial levels
- General environmental exposure of Hg not really a problem – levels in atmosphere and drinking water are relatively low

## EXPOSURES :

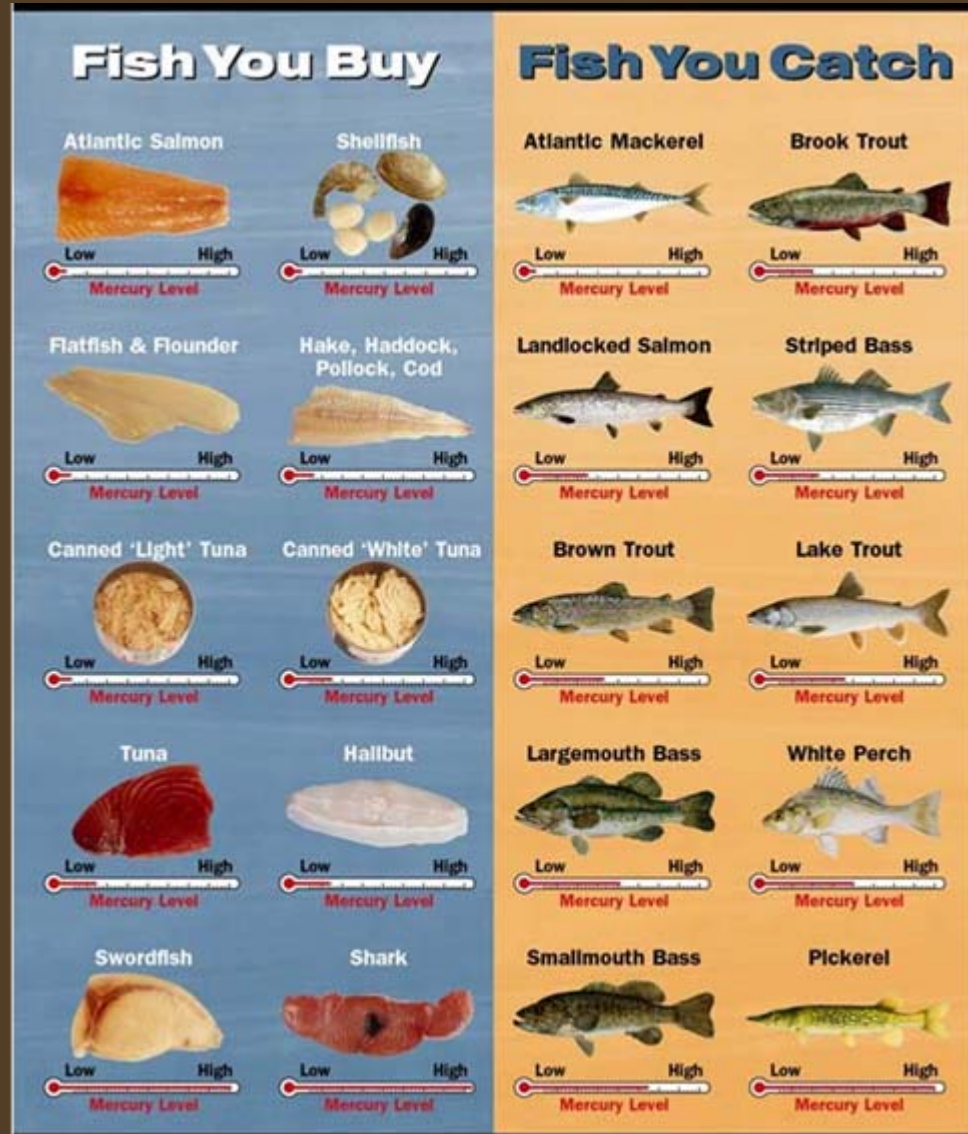
# Food

- Atmospheric Hg enters water where it is methylated by microorganisms, product is MeHg
- MeHg then enters aquatic food chain and bioconcentrates
- In sea mammals, Hg in tissue can rise to levels millionfold higher than those in surrounding water
- From bioconcentration comes human dietary exposure
  - FDA estimates exposure of 0.05 ug/kg/day → 3.5 ug/day for adult of average weight
- Unlike PCB's (deposited in fat), levels of MeHg (deposited primarily in protein) cannot be reduced by cooking
- Inorganic Hg compounds also found in food but sources are unknown and amounts ingested are far below toxic intake

## EXPOSURES :

Species	Mean Hg Conc. (ppm)	Data Source
Scallops	0.05	NMFS Report, 1978
Cod	0.11	FDA Survey, 1990-2003
Tuna, Canned	0.12	FDA Survey, 1990-2003
Halibut	0.26	FDA Survey, 1990-2002
Swordfish	0.97	FDA Survey, 1990-2002
Shark	0.99	FDA Survey, 1990-2002

Source: FDA



Source: State of Maine Department of Health & Human Services

(FDA current limit on commercial foods is 1 ppm)

Instructor Dr. Eckhert EHS201 UCLA 2005

## EXPOSURES:

# Occupation

- Inhalation of Hg vapor from working environment
- Uses:
  - Chlor-alkali industry (use as cathode in electrolysis of brine)
  - Dentistry (amalgam tooth filling)
  - Extraction of gold (esp. in developing countries – used to form amalgam with gold, amalgam heated to drive off Hg, results in atmospheric release)
  - Making scientific instruments and electrical control devices

## EXPOSURES:

# Other

- Dental amalgam fillings (mixture usually 50% Hg)
  - Major source of Hg vapor affecting general public
  - Very small amounts slowly released from surface of filling due to corrosion, chewing, grinding
  - Estimated release of 3-17 ug/day (can contribute to up to 40% of daily Hg exposure)
  - Amount inhaled low compared to toxic levels
- Religious practices
  - Santeria (Cuban), Voodoo (Haitian), Palo Mayombe (Caribbean), Espiritismo (Puerto Rico)
  - Metallic Hg sold as “azogue” – sprinkled in home & car, mixed in bath water & perfume, placed in candles, etc.
- Household products
  - Thermostats, fluorescent light bulbs, barometers, glass thermometers, blood pressure devices
- Outdated medicinal products containing mercurous chloride
  - Laxatives, teething powders

# Exposure Pathways & Absorption

- Metallic (Elemental)
  - Ingestion – *ex. liquid Hg swallowed from a broken thermometer*
    - 0.01% absorbed through GI, slow process and generally thought to be of no consequence
  - Inhalation – *ex. Hg vapors breathed in (occupational, dental fillings)*
    - 80% absorbed into lungs and dissolved into bloodstream
- Inorganic
  - Inhalation – *ex. mercurous chloride powder inhaled*
  - Dermal Contact – *ex. mercurous chloride powder spilled on skin*
  - Generally <10% absorbed (although can be up to 40%)
- Organic
  - Ingestion – *ex. exposed to HgMg through consumption of fish*
  - Inhalation – *ex. organic vapors breathed in as they evaporate slowly at room temperature*
  - Dermal Contact - *ex. dimethylmercury spilled on skin*
  - 90-95% absorption

# Diffusion

- Hg rapidly disperses to tissues, including brain
  - Both inorganic & organic forms have an affinity for thiol groups (-SH)
  - Thiol groups contained in most proteins and enzymes of body → binding of Hg to all body tissues
- All forms capable of crossing placental barrier
  - Fetal uptake greater with elemental & organic Hg
  - Severe consequences for health of fetus
  - Further neonatal exposure possible through breastfeeding → breast milk may contain 5% Hg concentration of maternal blood

# Accumulation

- Metallic (Hg vapor)
  1. Kidneys
  2. CNS
    - If metallic Hg enters the brain, converted to inorganic form and “trapped”
- Inorganic
  1. Kidneys
    - Does not enter brain as easily as other forms
- Organic
  1. Brain (posterior cortex)
    - Can be converted to inorganic form here and trapped

# Excretion

- **Metallic**
  - Most leaves via urine or feces after weeks/months
  - Small amounts exit via exhaled breath
- **Inorganic**
  - Most leaves body via urine or feces after several weeks/months
  - Small amount can be changed by body into metallic Hg and exit via breath
  - Also passed out through breast milk, intestinal mucosa, sweat glands, & salivary glands
- **Organic**
  - Leaves after several months mostly as inorganic Hg in the feces
  - Like inorganic, small amounts passed out through other means (see above)
- **Biomonitoring**
  - Hg concentrations in humans have been determined in blood, urine, body tissues, hair, breast milk, & umbilical cord blood

*HEALTH EFFECTS:*

# “Mad Hatter’s Disease”

- In Alice in Wonderland, the Mad Hatter was based on hat makers commonly affected by a brain disease due to use of mercury salts in the treatment of hat felt



## HEALTH EFFECTS:

# Chronic & Acute Exposure

### Chronic, low-dose exposure...

- Erethism (nervousness, irritability, mood instability, blushing)
- Tremor
- Personality change
- Suicidal tendency
- Paraesthesia (“pins & needles” sensation)
- Impaired hearing
- Speech disorders
- Visual disturbance
- Abnormal reflexes
- Disturbed gait
- Gingivitis
- Impaired nerve conduction
- Renal damage
- Adverse outcome of pregnancy
- Infertility
- Pneumonitis (lung disease)
- Glioblastoma (brain cancer)
- Immune system dysfunction

### Acute, high-dose exposure...

- Gastroenteritis (upset stomach)
- Mouth pain
- Abdominal pain
- Vomiting
- Excessive salivation
- Anuria (urine production stops)
- Uraemia (urine products appear in blood)
- Nephritis (kidney disease leading to kidney failure)
- Anorexia
- Ataxia (difficulty moving)
- Death

\*\*\* EPA has classified MeHg and mercuric chloride (inorganic Hg compound) as a Group C possible human carcinogens

# Reproductive Health

- Hg can impair fertility and outcome of pregnancy (malformations & aborted pregnancy)
- Because Hg can pass through placenta, fetus is at risk to exposure
  - Exposure in the womb can impair neurological development of fetus - cognitive thinking, memory, attention, language, fine motor and visual spatial skills
- In men, organic Hg can cause hypospermia (reduction in libido & impotence in some)
- Other reports of adverse effect of Hg on sperm motility

# Determinants of Risk

- Chemical form of Hg (MeHg more toxic than elemental)
- Dose
- Age of person exposed (fetus is most susceptible)
- Duration of exposure
- Route of exposure (inhalation, ingestion, dermal contact)
- Health of person exposed

# Risk Classifications

- **Metallic Hg**
  - Class D, not classifiable as a human carcinogen
  - Inhalation Reference Concentration (RfC) = 0.3 ug/cu.m
    - Lowest observed adverse effect level (LOAEL) = 25 ug/cu.m (tremor, memory dysfunction)
- **Mercuric chloride (HgCl<sub>2</sub>)**
  - Class C, possible human carcinogen
  - Oral Reference Dose (RfD) = 0.3 ug/kg/day
    - LOAEL = 633 ug/kg/day (autoimmune effects)
- **MeHg**
  - Class C, possible human carcinogen
  - Oral Reference Dose (RfD) = 0.1 ug/kg/day
    - Benchmark Dose = 46-76 ppb in maternal blood, 0.857-1.472 ug/kg/day (neuropsychological effects)

\*\*\*RfD/RfC is an estimate of daily exposure of human population (including sensitive subgroups) that is likely to be w/o an appreciable risk of deleterious effects during a lifetime

REGULATIONS:

# Occupational Standards & Guidelines

GOVERNING BODY		INORGANIC	ARYL	ALKYL
<b>OSHA</b>	PEL-TWA	0.01 mg/m <sup>3</sup>	---	0.01 mg/m <sup>3</sup>
	PEL-Ceiling	---	0.1	0.04 mg/m <sup>3</sup>
<b>ACGIH</b>	TLV-TWA	0.025 mg/m <sup>3</sup> , skin	0.01 mg/m <sup>3</sup> , skin	0.01 mg/m <sup>3</sup> , skin
	TLV-STEL	---	---	0.3 mg/m <sup>3</sup> , skin
	BEI-urine	35 ug/g creatinine	---	---
	BEI-blood	15 ug/L	---	---
<b>NIOSH</b>	REL-TWA	0.05 mg/m <sup>3</sup> , skin	0.05 mg/m <sup>3</sup> , skin	0.01 mg/m <sup>3</sup> , skin
	REL-ST/Ceiling	0.1 mg/m <sup>3</sup> (C), skin	0.1 mg/m <sup>3</sup> (C), skin	0.03 mg/m <sup>3</sup> (ST), skin
<b>IDLH</b>		10 mg/m <sup>3</sup>	10 mg/m <sup>3</sup>	2 mg/m <sup>3</sup>

REGULATIONS:

# Environmental Standards

GOVERNING BODY		REGULATION
<b>EPA</b>	Mercury-Containing and Rechargeable Battery Management Act of 1996	<ul style="list-style-type: none"><li>•Phases out use of Hg in batteries</li><li>•Applies to battery &amp; product manufacturers, battery waste handlers, &amp; battery importers/retailers</li></ul>
	Clean Air Act ( <i>EPA 1975a, 1975b, 1995a, 1996b</i> )	<ul style="list-style-type: none"><li>•Hg designated a “hazardous air pollutant”</li><li>•Gives EPA authority to regulate power plant Hg emissions by establishing “performance standards” or “maximum achievable control technology” (MACT)</li><li>•Clean Air Mercury Rule (March 15, 2005) – performance standards &amp; permanent, declining cap on Hg emissions</li></ul>

REGULATIONS:

# Environmental Standards cont.

<b>EPA</b>	Resource Conservation and Recovery Act (RCRA)	<ul style="list-style-type: none"><li>•Requires Hg to be managed as a hazardous waste</li><li>•States responsible for implementing – can be more stringent</li></ul>
	Comprehensive Environmental Response , Compensation, & Liability Act (CERCLA) ( <i>EPA 1995i</i> )	<ul style="list-style-type: none"><li>•Hg ranked 3<sup>rd</sup> behind arsenic &amp; lead on 2003 priority list of hazardous substances</li><li>•Hg compounds designated [extremely] hazardous substances</li><li>•Environmental media must be notified of environmental releases greater than the “reportable quantity” of 1 lb</li></ul>
	Safe Drinking Water Act ( <i>FSTRAC 1995</i> )	<ul style="list-style-type: none"><li>•Sets Maximum Contaminant Level (MCL) of 0.002 mg/L (inorganic compounds) for drinking water</li><li>•Applies to public water systems</li></ul>
	Clean Water Act ( <i>EPA 1992</i> )	<ul style="list-style-type: none"><li>•Hg regulated as a “priority pollutant”</li><li>•Establishes structure for regulating discharge of pollutants into waterways</li></ul>

## REGULATIONS:

# Clear Skies Act

- Clear Skies Act of 2003 = proposed federal law of the US, "a bill to amend the Clean Air Act to reduce air pollution through expansion of cap-and-trade programs"
- First submitted to House & Senate in 2002, later reintroduced as Clear Skies Act of 2003 in 2003 and once again in Senate as the Clear Skies Act of 2005 on January 24, 2005
- Proposes cut of Hg emissions by 69 percent – would cut 1999 emissions from 48 tons to a cap of 26 tons in 2010, and to a cap of 15 tons in 2018

EPA: "EPA continues to believe this legislative approach is the preferred option to achieve these important reductions; however, since the Congress has yet to act, the Agency issued CAIR and the Clean Air Mercury Rule to provide communities with tools to solve the problem of pollution transported from other states"

NRDC: "targets are *weaker* than those that would be put in place if the Bush administration simply implemented and enforced the existing law! Compared to current law, the Clear Skies plan would allow three times more toxic mercury emissions...It would also delay cleaning up this pollution by up to a decade compared to current law and force residents of heavily-polluted areas to wait years longer for clean air compared to the existing Clean Air Act"

# Food/Drug Regulations & Guidelines

GOVERNING BODY		REGULATION
<b>FDA</b>	Food Regulation ( <i>FDA 1994, 1995, 1998</i> )	<ul style="list-style-type: none"> <li>•Sets action levels for Hg in food</li> <li>•1 ppm – fresh, frozen or processed fish, shellfish, etc. and wheat-pink kernels</li> <li>•0.002 ug/L – bottled water</li> </ul>
	Cosmetics Regulation ( <i>FDA 1974</i> )	<ul style="list-style-type: none"> <li>•Eye area cosmetics must contain &lt;65 ppm Hg (Hg calculated as the metal)</li> </ul>
	Consumer Advisory ( <i>FDA 2004</i> )	<ul style="list-style-type: none"> <li>•Women pregnant or of childbearing age should not eat shark, swordfish, king mackerel, or tilefish</li> <li>•7 oz/wk consumption of fish with average Hg levels of 1 ppm</li> <li>•14 oz/wk consumption of fish with average Hg levels of 0.5 oz/wk</li> </ul>

# International Guidelines

- World Health Organization
  - Drinking water guideline of 0.001 mg/L – applies to all forms of Hg (*WHO 1984*)
  - Permissible tolerable weekly intake of 5 ug/kg total Hg or 3.3 ug/kg MeHg (*WHO 2003*)

# State Legislation

- Amount of legislation varies greatly state to state
  - MA → 23
  - OK → 1
- California → 12
  - AB 455 – toxics in packaging
  - AB 999 – insurance requirements for alternatives to Hg amalgam fillings
  - AB 1369 – bans sale of Hg thermostats by 1/1/06 w/ exemptions, bans land filling thermostats
  - AB1699 – establishes Mercury Recycling Enhancement Act, bans disposal of fluorescent lights in solid waste facilities
  - AB 2901 – requires recycling of cell phones due to Hg
  - AB 2943 – Mercury Pollution Prevention Act of 2004, prohibits sale of products w/ added Hg beginning 2006 at 1,000 mg/product, reducing to 10 mg/product in 2008
  - SB 20 – creates electronics recycling program
  - SB 633 – Mercury Reduction Act of 2001, prohibits sale of vehicles after 1/1/05 that contain Hg switches
  - AB 966 – requires DHS to establish regulations for amalgam use in dentistry
  - AB1415 – prohibits selling or distributing Hg switches or relays
  - SB 1180 – requires purchaser of fluorescent lamp to pay recycling fee to retailer
  - AB 1255 – requires CA Dept. of Toxic Substances Control to provide list of sources of Hg in products

## ALTERNATIVES & SOLUTIONS:

# Elimination & Substitution?

- Cannot eliminate completely b/c Hg is naturally occurring, but...
- Substitution
  - Thermometers → non-Hg alcohol & mineral-spirit filled thermometers
  - Manometers, barometers, vacuum gauges → electronic (digital) gauges, aneroid (ex. Bourdon tube, diaphragm, piston, capsule) pressure gauges
  - Blood pressure units → aneroid sphygmomanometers
  - Thermostats → air-controlled, reed switch, vapor-filled diaphragm, snap-switch, programmable electric
  - Hg switches & relays → hard-contact switches, solid-state switches, electro-optical switches, inductive sensors, capacitive sensors, photoelectric sensors, ultrasonic sensors
  - Mercuric chloride antiseptics & disinfectants → alcohol, hydrogen peroxide
  - Dental amalgams → Composites, pit-fissure sealants, glass ionomers, gold foil, cast metal & metal-ceramic (problems of cost & appropriateness with all)
  - Coal → alternative raw material like natural gas, coal-type with special constituents (ex. more Cl) that allow for better control of Hg, use of coal with lower trace Hg content\*\*

# Reducing Exposure?

- Reducing MeHg intake – adhere to FDA guidelines regarding fish intake
- Alternative processes
  - Gold extraction → Minataur process cyanidation process non-mercury electrolytic process
- Proper management & control
  - Fluorescent lights → recycling (“low-mercury” bulbs also available)
  - Hg waste management
  - End-of-pipe control techniques → exhaust gas filtering (fossil-fueled power plants, cement production, extraction processes)
  - Pretreatment measures (coal washing, waste separation) or combustion modifications (fluidized bed combustor, mass burn/waterwall combustor, low-NO<sub>x</sub> burner)
- Reducing consumption of raw materials that generate Hg releases
  - Emissions standards

# Summary

- Hg is highly prevalent & persistent in the environment
- We increase our exposure to Hg primarily through food & occupational activities
- Acute and chronic exposure to Hg can result in deleterious health effects, primarily to the brain & CNS
- Pregnant women and their fetuses are of special concern due to Hg's ability to cross the placental barrier
- Hg is highly regulated and continues to be the topic of heavy debate in governmental settings
- To reduce our exposure to Hg, we should be aware of our seafood consumption as well as of Hg-containing equipment & instruments
- Hg remains an extremely important agent with regards to environmental health

# References:

- Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Mercury, 1999. <http://www.atsdr.cdc.gov/toxprofiles/tp46.html>
- Environmental Protection Agency (EPA). Air Toxics Website: Mercury Compounds Hazard Summary, 1992. <http://www.epa.gov/ttn/atw/hlthef/mercury.html>
- Environmental Protection Agency (EPA). Integrated Risk Information System: Mercury, elemental, last revised 2005. <http://www.epa.gov/iris/0370.htm>
- Environmental Protection Agency (EPA). Integrated Risk Information System: Methylmercury, last revised 2001. <http://www.epa.gov/iris/0370.htm>
- Occupational Health & Safety Administration (OSHA). Mercury OSHA Standards. <http://www.osha.gov/SLTC/mercury/standards.html>
- Occupational Health & Safety Administration (OSHA). Mercury Properties and Health Effects. [http://www.osha.gov/SLTC/mercury/properties\\_health.html](http://www.osha.gov/SLTC/mercury/properties_health.html)
- U.S. Food & Drug Administration (FDA). Pesticides, Metals, Chemical Contaminants, & Natural Toxins: Mercury. <http://www.cfsan.fda.gov/~lrd/pestadd.html#metals>
- World Health Organization (WHO). Concise International Chemical Assessment Document – Elemental Mercury & Inorganic Mercury Compounds, Human Health Aspects, 2003. <http://whqlibdoc.who.int/publications/2003/9241530502.pdf>
- World Health Organization (WHO). Mercury in drinking water, 2005. [http://www.who.int/water\\_sanitation\\_health/dwq/chemicals/mercuryfinal.pdf](http://www.who.int/water_sanitation_health/dwq/chemicals/mercuryfinal.pdf)
- World Health Organization (WHO). UN recommends new dietary intake limits for mercury, 2003. <http://www.who.int/mediacentre/news/notes/2003/np20/en/>