UNITED NATIONS
ENVIRONMENT PROGRAMME

CHEMICALS

UNEP

REGIONAL AWARENESS-RAISING WORKSHOP ON MERCURY POLLUTION

A global problem that needs to be addressed

Buenos Aires, Argentina,
13 – 16 September 2004

IOMC INTER-ORGANIZATION PROGRAMME FOR THE SOUND MANAGEMENT OF CHEMICALS

A cooperative agreement among UNEP, ILO, FAO, WHO, UNIDO, UNITAR and OECD

Overview of exposures and health effects of mercury for humans and wildlife

by Roberto Lucchini, resource person

Slide 1

Overview of Exposures & Health Effects of Mercury for Humans and Wildlife

Mercury Awareness Raising Workshop
Buenos Aires, Argentina
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oberto Lucchini MD
stitute of Occupational Health
niversity of Brescia, Italy
cchini@med.unibs.it

1

Slide 2

Outline

- Primary routes & exposure sources
- Toxicity in humans & reference values
- Examples of population exposures
- Wildlife effects

2

Slide 3

Major Exposure Pathways

Elemental mercury (Hg^0) vapours:

- Dental amalgams for most people
- Occupations (such as thermometers, neon lamps, artisanal mining and chloralkali plants)
- Use of mercury in religious/cultural practices
- Other incidents (children playing with mercury)
- Spills (broken thermometers, thermostats, etc..)

Methylmercury (MeHg):

- Consumption of fish (tuna, sword fish) and marine mammals (certain whales, seals)

3

Slide 4

Humans are also exposed to other mercury forms:

- Inorganic mercury salts, mainly through ingestion:
  - Low levels in some foods (e.g. wild mushrooms)
  - Some traditional Asian medicines:
    - Cinnabaris (mercury sulfide)
    - Calomelas (mercuric chloride)
  - Skin lightening creams
- Ethylmercury from preservative (thimerosal, ethylmercury thiosalicylate) in vaccines
  - Use of thimerosal eliminated or reduced in many countries

4

Slide 5

Elemental Hg° Vapor - Toxicity

- Inhalation is main route of exposure
- Readily crosses blood brain barrier and placenta
- High exposures can cause death
- Nervous system is primary target of toxicity
  - Neurological effects include tremors, insomnia, memory loss, headaches
- Also toxic to kidney - In body, Hg^0 may be oxidized to inorganic mercury (Hg^{+2}), which accumulates in kidney

5

Slide 6

What Elemental Hg° Exposure Levels Are Safe?

- Long-term occupational exposures to air levels of 25-30 ug/m^3 has resulted in adverse effects on nervous system + kidney
- U.S. EPA "reference concentration" = 0.3 ug/m^3 (safe exposure level for all humans over a lifetime)
- E.U. recommends that average annual exposure should not exceed 0.05 ug/m^3
- Various Governments have established limits for worker exposures:
  - For example, in India short-term (15 minutes) air levels can not exceed 30 µg/m^3
  - ACGIH (American Conference Governmental Industrial Hygienists) Urinary Hg = 35 µg/g creatinine

6

Slide 7

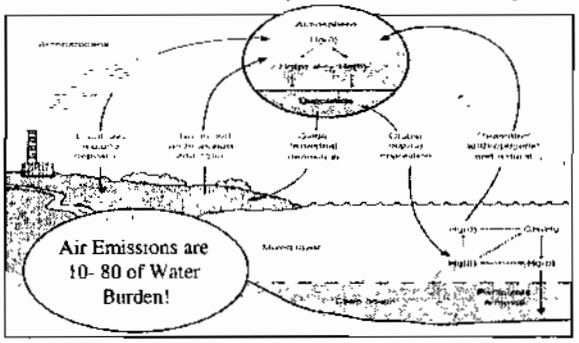
Exposures to Methylmercury (MeHg)

- Eating fish – an important part of a healthy diet -- is the main source of exposure to MeHg
- Typically about 0.05 to 1.4 ppm (or mg/kg) in fish
  - Levels vary by species, size, and age of fish
  - Also, vary by characteristics of waterbody (pH, redox potential, local contamination, and other factors)
  - Highest in large predatory marine species, such as shark, swordfish, large tuna, some whales, seals
  - Levels can also be high in predatory freshwater fish, such as pike, perch, tilapia

7

Slide 8

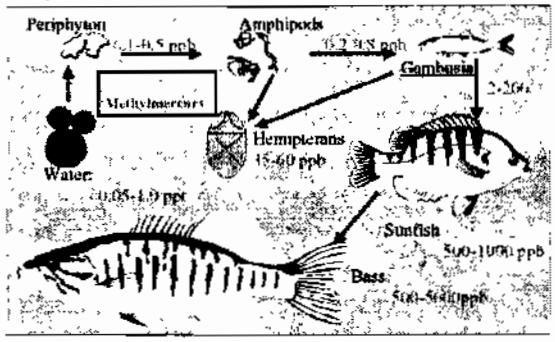
Geochemical Cycle of Mercury



Adapted from US Dept of Interior's Report on Hg in the Florida Everglades

Slide 9

Hg biomagnification in the foodchain



Cleckner et al., 1998, Biogeochemistry

Slide 10

Regional Fish Tissue Levels*

Location	Species	Concent. Wet wt, ppm	Year	C level**
Baltic Sea	Round fish	0.010 – 0.050	'94-98	B
	Marine fish	0.016 – 0.091		G
	Blue mussel	0.005 – 0.010		B
Finland	Northern Pike	1.52 (avg)	'60s	
		0.60 (avg)	'90	
Slovak Republic	Barbel	0.053 – 7.329	'95 – 00	
	Perch	0.009 – 1.964	'95 – 00	
	Grayling	0.032 - 0.110	'95 – 00	
	Rainbow Trout	0.001 - 0.970	'95 – 01	
	Eel	0.007 - 0.220	'95 - 96	
Italy	Blufin Tuna	0 – 4	?	G

*Data from UNEP Global Mercury Assessment ** B = background G= general, unspecified

Slide 11

Examples of Hg Levels (ppm) in fish from other regions (values obtained from UNEP 2002)

Location	Fish Species	Hg Conc.
Thailand	5 marine fish species	0.05 – 0.7
Fiji	Canned tuna	0.01 – 0.97
Philippines	Tilapia	0.1 – 0.5
Australia	Redfin Perch	0.12 – 1.3
UK	Swordfish	0.15 – 2.7
	Shark	1 – 2.2
Sweden	Northern Pike	0.1 – 2.0
U.S.A.	Large mouth bass	0.1 – 1.4

11

Slide 12

Exposure depends on amount of fish eaten & concentration of MeHg in fish

- Dose = $\frac{\text{amount fish ingested (g) x Hg level in fish (ug/g)}}{\text{body weight (bw)}}$
- Examples:
  - Ingestion of 500 g of tuna (with Hg level of 0.2 ppm) per week for a 60 kg women:
    - $\frac{500 \text{ g} \times 0.2 \text{ ug/g}}{60 \text{ kg}}$ = 1.7 ug/kg
  - 100 g of swordfish (with Hg level of 1 ppm) per week for a 60 kg women:
    - $\frac{100 \text{ g} \times 1.0 \text{ ug/g}}{60 \text{ kg}}$ = 1.7 ug/kg
  - FAO/ WHO PTWI = 1.6 ug/kg
  - Assumes no other exposures

12

Slide 13

MeHg absorption and metabolism

- Easily absorbed through GI, probably skin
  - Food type seems to make no difference in absorption; 95% of ingested MeHg is absorbed
  - MeHg is distributed throughout the body and easily passes the placenta and blood brain barrier
  - Half-life in body has been measured to be 35 to 190 days (average = 72 days)
- Associated with protein; accumulates in several tissues (brain, kidney)

13

Slide 14

MeHg Health Effects

- Spectrum of effects from adult exposure or during development – mortality through subtle effects on ability to learn
- Developing nervous system is a sensitive target for low dose MeHg exposure
- Evidence from human and animals of adverse effect on developing and adult cardiovascular system
- Animal evidence of immune and reproductive effects
- Not likely to be a human carcinogen

14

Slide 15

Most data are from humans

Severe poisoning events occurred in 1960s-70s in Minamata Bay, Japan and in Iraq

15

Slide 16

MeHg – Spectrum of Effects

- Effects on adults included death, paresthesia, tremors, ataxia, hearing and vision impairment, and balance and speech disturbances
- Children born to mothers exposed during pregnancy exhibited
  - Cerebral palsy, delayed walking/talking, delayed startle responses and other neurological effects
- Contemporary studies in children exposed *in utero*
  - Large studies of populations consuming seafood
  - Effects on auditory evoked potential, cardiovascular system and on tests associated with ability to learn and process information

16

Slide 17

What mercury exposure levels are toxic? What levels are safe?

- Most risk assessors and regulatory agencies use reference dose (RfD), acceptable daily intake (ADI), tolerable daily intake (TDI), minimal risk level (MRL)
- All assume a threshold for effect, presume there is a level with no effect or acceptable effect

17

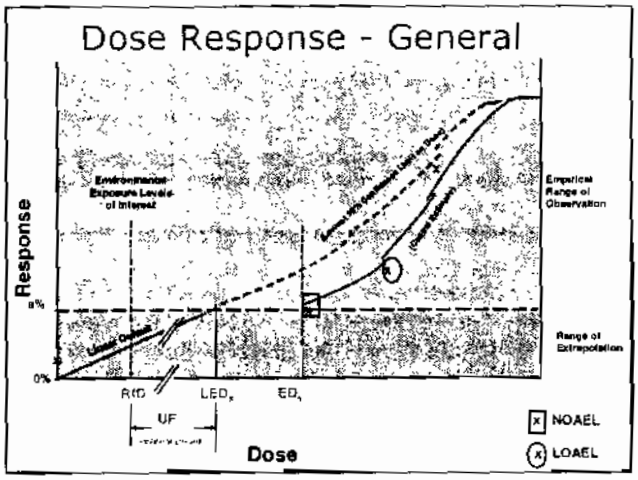
Slide 18

What MeHg Exposure Levels Are Toxic to Adults and Children?

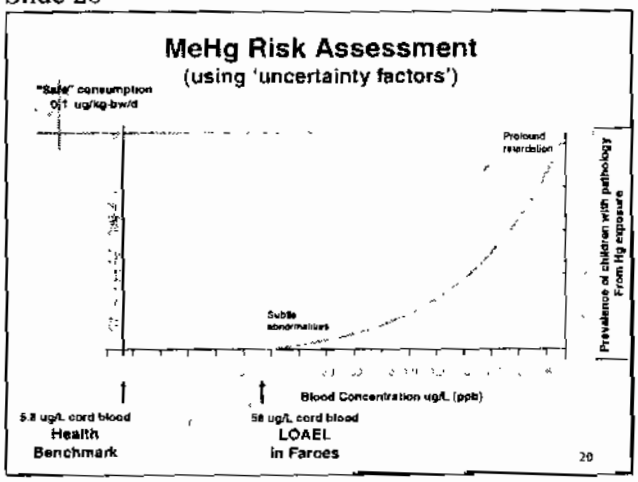
- WHO estimated that paresthesia occurred in 5% of population exposed at levels above 4 µg Hg per kilogram body weight per day (µg /kg/day) = about 50 ppm mercury in hair, or 200 ppb Hg in blood
- However, recent research indicates effects (cardiovascular) may occur at lower doses
- Data not available to determine the levels that cause effects in children
  - Consider however, that neurological development continues through adolescence

18

Slide 19



Slide 20



Slide 21

What MeHg Exposure Levels Cause Adverse Effects to Fetus?

- Fetus may be most sensitive to MeHg
  - Generally, developmental stages are most vulnerable to neurotoxicants
  - Effects noted in Iraqi and Japanese children born to mothers without symptoms
- 3 large recent studies of human subpopulations to determine toxic and safe Hg dose:
  - Faroe Islands
  - New Zealand
  - Seychelles

21

Slide 22

Faroe Islands Study

- Exposures mainly from pilot whale meat (with Hg levels about 2.0 ppm)
- 900 mother – child pairs
  - Measured mercury in hair and cord blood
  - Measured neurobehavioral development in children; smaller cohort tested for cardiovascular and other
  - Exposures associated with deficits in 8 or 10 separate measures in 7 year old children
  - Potential effects of PCB exposure accounted for
- Multiple "benchmark doses" (BMD) range from 24 – 103 ug/ l blood (about 11 ppm hair) which = a dose of about 1 ug/kg/day

22

Slide 23

Other Major Studies of MeHg human toxicity

- New Zealand Study:
  - 200 mother – child pairs
  - Effects noted on several measures in "standard IQ" tests
  - Median BMD = 24 ug/l blood (9 ppm hair) or about 1 ug/kg/day
- Seychelles:
  - 700 mother – child pairs
  - Exposures from fish diet (with Hg levels 0.2-0.3 ppm)
  - High exposure group had mean mercury hair level = 15 ppm
  - No adverse effects identified in children tested at various ages up to 66 months
  - NOAEL = 15 ppm hair (1.5 ug/kg/day)

23

Slide 24

Reference Levels: limits estimated to be safe for humans, including pregnant women

- FAO/WHO Expert Committee 2003 Provisional Tolerable Weekly Intake (PTWI) = 1.6 ug/kg bw = 0.23 ug/kg/day
  - Derived from BMD of 1.5 ug/kg/day divided by 6.4 to account for uncertainty and variability
- U.S. EPA Reference Dose = 0.1 ug/kg/day
  - BMD of 1 ug/kg/day divided by 10 to account for uncertainty and variability
- U.S. ATSDR "minimal risk level" = 0.3 ug/kg/day
- Canada reference level = 0.2ug/kg/day
- European Union level = 0.1 ug/kg/day

24

Slide 25

Population mercury exposure studies – examples described in UNEP 2002

- Mercury Exposures in Finland (Louekari, et. al. 1994):
  - "Farmer segment" - subpopulation with higher consumption of locally caught fish
  - Exposures estimated using dietary survey data, and data on mercury levels in fish
  - Mean exposure = 0.3–0.4 ug/kg/day in 1968, and 0.2–0.3 ug/kg/day in 1990

25

Slide 26

Mercury Exposures in U.S.A. (Schober et al., 2003)

- Measured mercury levels in blood and hair in representative sample of U.S. including 1709 women of childbearing
- Also conducted medical exam and dietary survey
- About 8% had hair mercury levels > 1 ppm and blood mercury levels > 5 ppb, and
- Positive association between frequent fish consumption and higher mercury levels

26

Slide 27

Mercury Exposures in North Greenland (Hansen and Pedersen, 1986)

- Measured mercury levels in blood
- 16% of adults had blood levels > 200 ppb (= dose of about 4 ug/kg/day)
- 80% had blood levels > 50 ppb (= dose of about 1 ug/kg/day)
- Positive association with ingestion of marine mammals

27

Slide 28

Mercury Exposures in Papua New Guinea (Suzuki, 1991)

- Measured mercury hair levels in people in 3 villages (seaside, riverside, and inland) not influenced by local releases
- Seaside village (Dorogi) had mean hair levels of 4.1 and 4.4 for men and women, respectively (= dose of about 0.4 ug/kg/day)
- Levels were slightly lower in riverside village (about 6 km from coast), and lowest in inland community (25 km from coast)

28

Slide 29

So, Who Is at Risk?

- Fish is good/nutritious food, consumed in moderation
- However, people who consume substantial amounts of contaminated fish and/or marine mammals are "at risk"
  - Women of childbearing have potential to expose developing fetus
  - Children eat more food on body weight basis than adults and are still developing, so may be at higher risk than adults
- Some occupations
  - Artisanal miners, chloralkali plant workers....
- People living near spills, especially indoor spills
- Possibly some other subgroups using
  - traditional medicines, cosmetics, ritualistic uses...

29

Slide 30

Hg Exposures for Wildlife

- Wildlife species that rely on fish as a large part of their diet can have elevated mercury levels
- Examples include: otter, mink, raptors, eagles, osprey, seals, some whales
- For example, mercury levels in arctic ringed seals and beluga whales have increased by 2 to 4 times over the past 25 years (based on studies in Canada)

30

Slide 31

Effects in wildlife 1

- Fish-eating animals and those that prey on fish-eaters are the most exposed population.
  - But effects have been measured in insect-eating songbirds
- Mercury affects the nervous system and causes reproductive abnormalities.
  - Birds in Minamata had difficulty flying, and exhibited other severe abnormal behavior. Waltzing cats.
  - Mating behaviors may be impaired.
  - Laboratory studies have shown impairment in mink, cats, mallards and wading birds
  - Field data strongly suggest that adverse effects in common loons are due to accumulation of mercury originating from air emissions.
  - Field data also suggest adverse effects due to mercury in the Florida panther, but the origin of this mercury may be from both air and other types of sources.

31

Slide 32

Effects in wildlife - 2

- Adverse effects of MeHg on reproduction can occur at egg concentrations as low as 0.05 to 2.0 mg/kg.
  - Eggs of certain Canadian species are in this range
  - Concentrations in several other species are approaching these levels
- Effects on fish are beginning to be demonstrated
- Mercury may also harm soil communities by decreasing microbiological activity

32

Slide 33

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33