National Institute for Minamata Disease

Ministry of the Environment, Japan

NIMD Forum 2008

Mercury Recycling and Environmental Monitoring for a Sustainable Society

27 March 2008

Conference Hall, Minamata Disease Archives

National Institute for Minamata Disease

Minamata City, Kumamoto, Japan

Programme

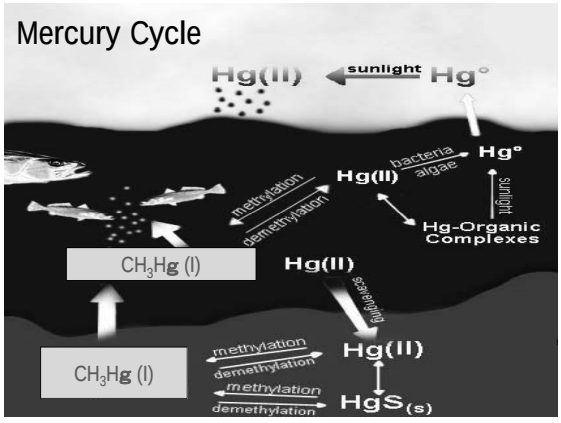
		Pages
Opening Session		
9:45 - 9:50	**Opening Remarks**	
9:50 - 10:00	**Global Mercury Pollution and Exposure** Dr. Hirokatsu Akagi (ex. NIMD)	1
10:00 - 10:30	**Construction of a "Model Environmental City" based on the Experience of and Lessons from the Tragedy of Minamata Disease** Mr. Tomofumi Tanoue (Minamata City Government)	5
10:30 - 10:45	Break	
10:45 - 11:30	**Treatment Techniques of Soil Which Was Contaminated by Mercury in Japan** Dr. Akito Matsuyama (NIMD)	12
11:30 - 12:15	**Zero Mercury Emission Strategy in Sweden** Dr. Lars D. Hylander (Uppsala University)	16
12:15 - 13:15	Lunch	
13:15 - 13:45	**Mercury Monitoring in Air and Wet Depositions in Japan** Dr. Koji Marumoto (NIMD)	30
13:45 - 14:30	**Life-cycle Flow Management of Mercury** Dr. Misuzu Asari (Kyoto University)	35
14:30 - 15:15	**Progress of Mercury Analysis and the Significance of Monitoring and Quality Control** Dr. Milena Horvat (The Jožef Stefan Institute)	45
15:15 - 15:30	Break	
15:30 - 16:00	**UNEP Mercury Programme and Activities on the Environmentally Sound Management of Mercury Waste** Dr. Desiree Narvaez (UNEP Chemicals)	55
16:00 - 16:45	**Risk Assessment of Industrial Chemicals Aiming at Better Risk Management** Dr. Akihiro Toukai (National Institute of Advanced Industrial Science and Technology)	63
16:45 - 16:50	**Closing remarks**	

International collaborative research activities in NIMD

Hirokatsu Akagi

International Collaboration on Global Environmental Mercury Research in NIMD (1992- present)

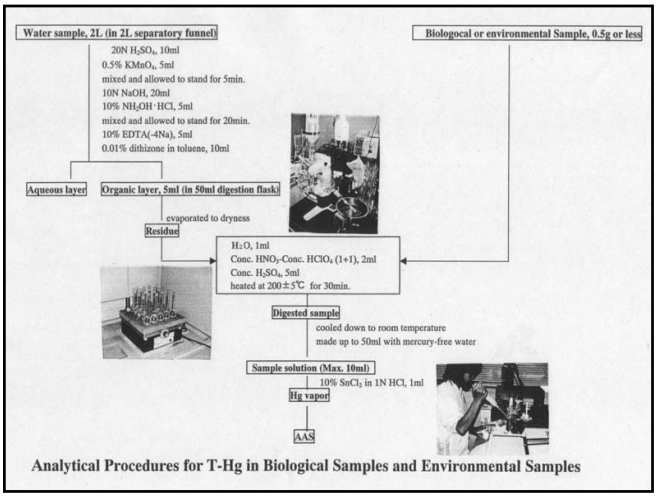
1. Mercury Pollution Due to Gold Mining
   Brazil, Indonesia, Philippines, Vietnam, Tanzania, China, etc
   Global Environmental Research Project (1992-1995):
   Human and Environmental Exposure Assessment
   -Evaluation of actual extent of environmental contamination and its possible health effects; Pathways of mercury exposures; detailed mercury speciation analysis and its quality control; Technical transfer of analytical methods, etc
2. Global Exchange of Information – Workshop/Symposia
3. Cooperation with International Agencies
   Designated as a WHO collaborating center in 1986
   IAEA Coordinated Research Projects:
   -Isotope studies of the biogeochemistry of mercury in polluted environments
   -Health impacts of mercury cycling in contaminated environments studied by nuclear techniques
4. SCOPE Mercury Projects (ICSU):
   - Evaluation of the role and distribution of mercury on ecosystems with special emphasis on tropical regions



Mercury Dynamics in Aquatic Ecosystems - Ottawa River Project -

Radiochemical Methods for Mercury Speciation:
Simultaneous extraction of Hg and MeHg as the dithizonates
- TLC separation - Gamma counting

- Isotopic organic and inorganic mercuric exchange in river water, *Environ. Sci. Technol.*, **11** (9), 907-909 (1977)
- Equilibrium concentration of methylmercury in Ottawa river sediments, *Nature*, **270**, 419-420 (1977)
- Mercury methylation and partition in aquatic systems *Bull. Environ. Contam. Toxicol.*, **23**, 372-376 (1979)
- pH affects mercury distribution, not methylation *Ecotoxicol. Environ. Safety*, **3,** 36-38 (1979)
- Mercury in Ottawa river, *Environ. Res.*, **19,** 231-243 (1979)
- Quantitative analysis of methyl and inorganic-mercury from mammalian, fish and plant tissues, *Environ. Pollution (Series B),* **2**, 345-357 (1981)



Analytical Procedures for T-Hg in Biological Samples and Environmental Samples

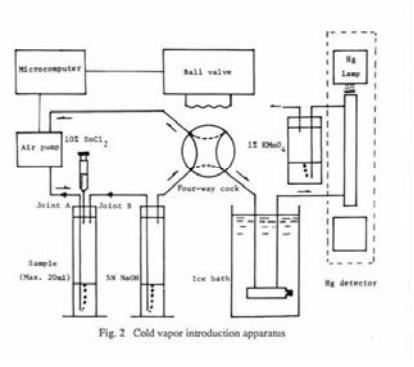
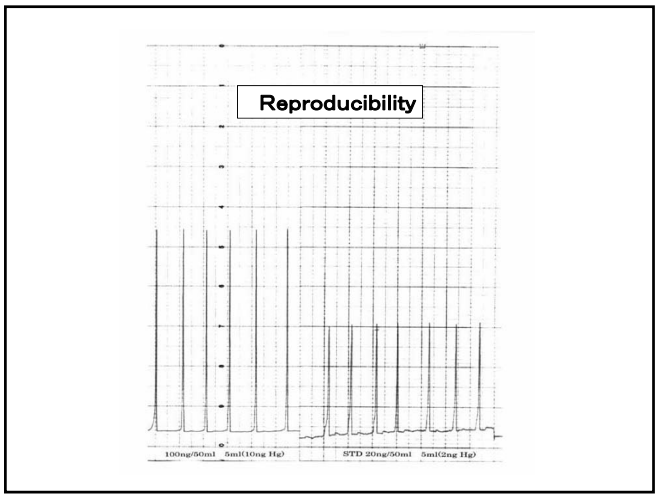
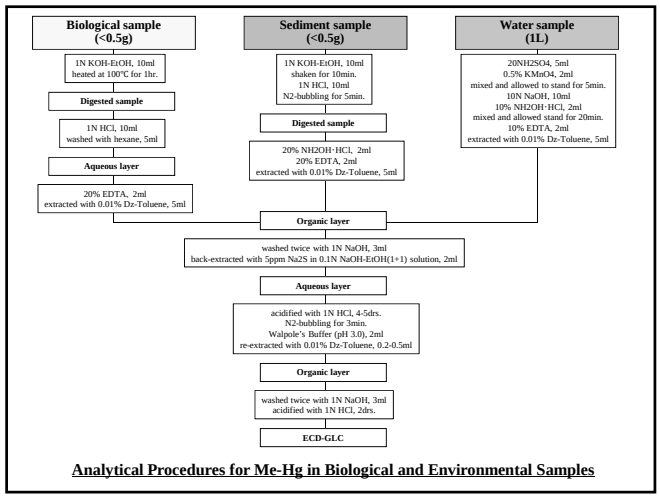
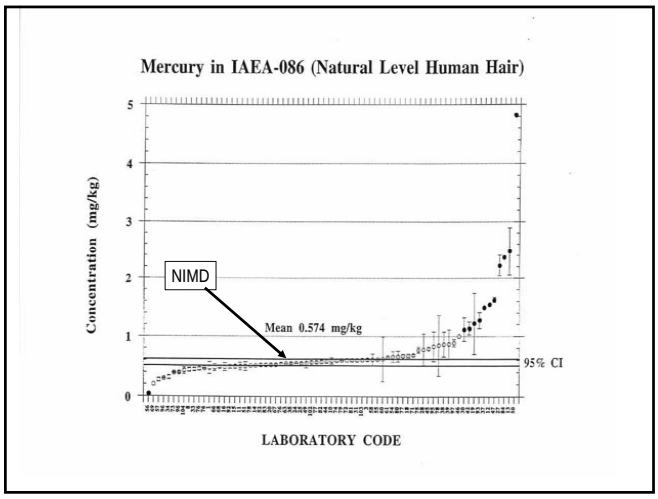


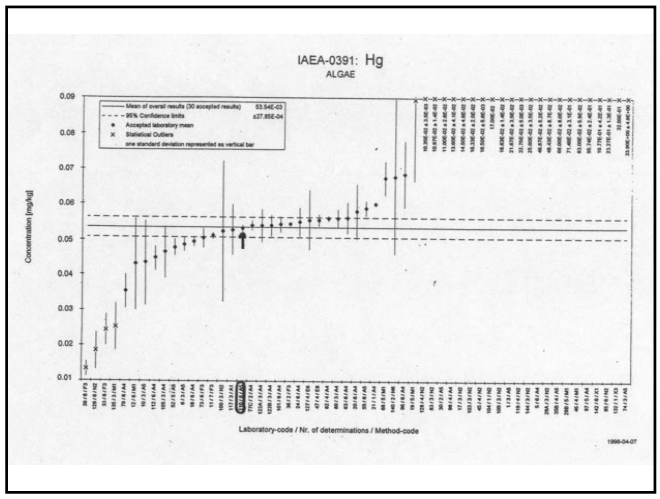
Fig. 2 Cold vapor introduction apparatus

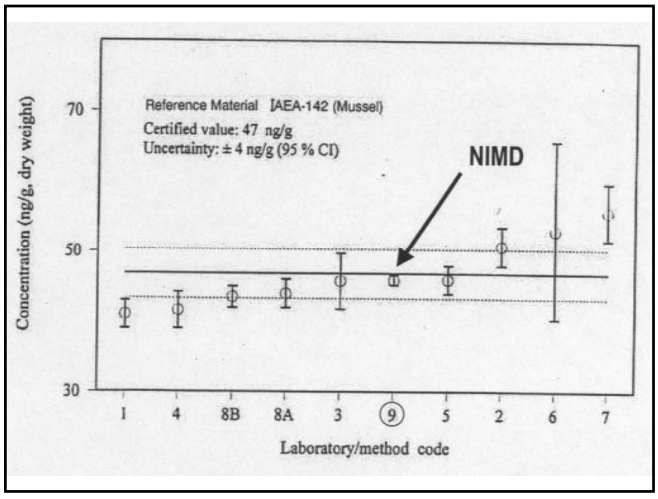


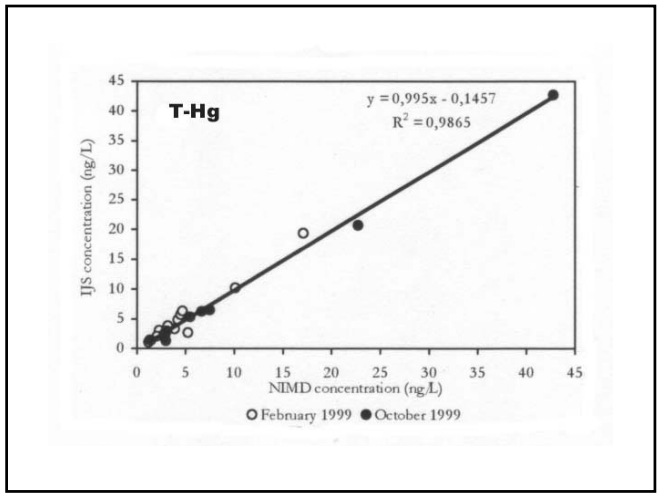


Analytical Procedures for Me-Hg in Biological and Environmental Samples









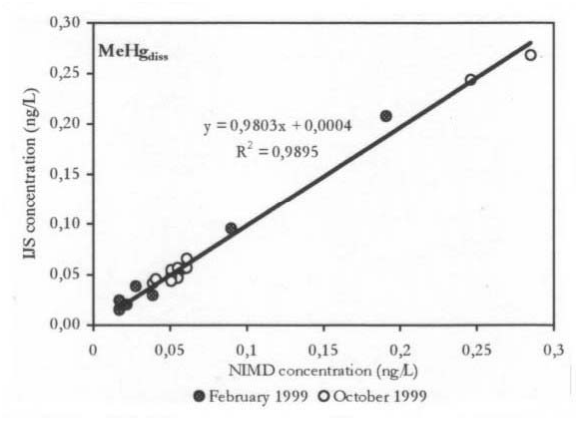
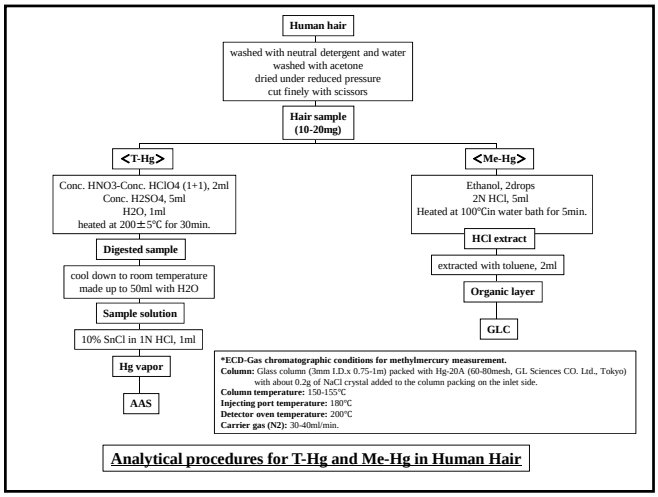


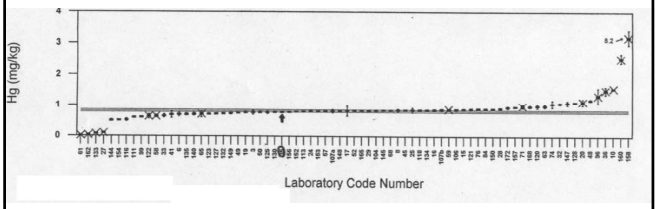
Table 1. Equilibrium distribution of mercury in sediment-water-fish systems after

		Aquatic system		
		AQ1	AQ2	AQ3
Hg^{2+} added to river sediment		1ppm	5ppm	10ppm
Hg in sediment (ppb)	Inorganic	848	4,153	8,378
	Methyl	17.62	31.61	31.49
	%Methyl	2.03	0.76	0.37
Hg in whole water (ppb)	Inorganic	0.015	0.044	0.052
	Methyl	0.034	0.014	0.019
	%Methyl	70.22	23.78	27.01
Sediment/water (Partition coefficient)*	Inorganic	5,800	94,500	161,000
	Methyl	500	2,300	1,600
Hg in fish (ppb)	Inorganic	8.7	12.7	67.2
	Methyl	333.7	308.3	274.6
	%Methyl	97.5	96.1	80.3
Fish/water (bioaccumulation factor)	Methyl	9,700	22,500	14,300

* Relative affinity for sediment measured as ppb Hg in sediment (dry weight) ppb Hg in water



Analytical procedures for T-Hg and Me-Hg in Human Hair



Analytical Methods for Mercury and Methylmercury in Biological and Environmental Samples

[A] Total mercury:
Wet digestion – CVAAS (Closed circulation - open air flow system)

[B] Methylmercury:
Dithizone extraction – GC-ECD
HCl leaching – toluene extraction – GC-ECD (for hair MeHg)

Akagi, H. Nishimura, H.: Speciation of mercury in the environment, *In: Advances in Mercury Toxicology*, (Edited by T. Suzuki, N. Imura and T. W. Clarkson, Plenum Press, USA), pp. 53-76 (1991)

- Standard Methods of Analysis for Hygienic Chemists –With Commentary- authorized by the Pharmaceutical Society of Japan (1990)
- Standard Methods of Analysis in Food Safety Regulation-Chemistry (The Ministry of Health and Welfare,1991)
- Standard Methods of Analysis in Food Safety Regulation-Chemistry (The Ministry of Health, Labor and Welfare, 2005)
- Mercury Analysis Manual (The Ministry of the Environment, 2004)

Mercury Pollution Due to Gold Mining in the Amazon
- NIMD-UFRJ Joint research -

- Akagi, H. et al.: Methylmercury pollution in the Tapajos river basin, Amazon, *Environ. Sci.*, **3**(1), 25-32 (1994)
- Akagi, H. et al.: Methylmercury pollution in the Amazon, Brazil, *Sci. Total Environ.*, **175**, 85-95 (1995)
- Akagi, H. et al.: Human exposure to mercury due to gold mining in the Tapajos river basin, Amazon, Brazil: Speciation of mercury in human hair, blood and urine, *Water, Air, and Soil Poll.*, **80**, 85-94 (1995)
- Malm, O. et al.: Mercury and methylmercury in fish and human hair from the Tapajos river basin , Brazil,Sci. Total Environ., 175, 141-150 (1995)
- Akagi, H. et al.: Human exposure to mercury due to gold mining in the Amazon, Brazil - A Review, *Environ. Sci.*, **4**(3), 199-211 (1996)
- Kehrig, H.A. et al.: Methylmercury in human hair samples from different riverine groups, Amazon, Brazil, *Water, Air and Soil Poll.*, **97**, 17-29 (1997)
- Kehrig, H.A.: Methylmercury in fish and hair samples from the Balbina reservoir, Brazilian Amazon, *Environmental Research, Section A*, **77**, 84-90 (1998)
- Akagi, H.: Studies on mercury pollution in the Amazon, Brazil, *Global Environmental. Research*, **2**(2), 193-202 (1998)

Main co-workers in the long-term international collaborative research in NIMD:

Brazil
Drs. W.C. Pfeiffer, O. Malm, F.J.P. Branches, J.R.Guimaraes, R.B. Oliveira, H. A. Kehrig (UFRJ), T. Cid de Souza (DNPM), E. C.O. Santos, E. da Silva Brabo, F.F. Kleber (IEC), M. Costa, R. Meramed (SETEM)

Slovenia
Drs. M. Horvat, M. Logar, V. Fajon, I. Falnoga, S. Lojen, N. Ogrinc (IJS), R. Rajar, M. Cetina, D. Zagar (ULj)

Philippines
Drs. N. Cortes-Maramba, E.B. Torres, A. G.C. Ramirez, E.S.Castillo, A. Manglicmot, J.P. Reyes, N. Dando (UP) T. Francisco-Rivera (DOH)

Tanzania
Drs. J.R. Ikingura, J.M.J. Kahatano, S.R. Mnali, J.K. Mujumba, M.K.D. Mutakyawa, C.W. Messo (UDSM)

Indonesia
Drs. R. Purwana (UI), S. S. Soesanto (NIHRD), B. B. Edvantro, H. Syafrul, Asrul, Rita, H.Rachdiati, Darmaerius (EMC)

International Symposia/Workshops (2)

- NIES Symposium: Contemporary Issues in Heavy-Metal Related Toxicology, Tsukuba, JAPAN (Apr. 1996)
- The 4th International Conference on Mercury as a Global Pollutant, Hamburg, GERMANY (Aug.1996)
- International Workshop on Fate of Mercury in Gold Mining and Measures to Control the Environmental Pollution in Various Countries, Jakarta, INDONESIA (Nov. 1996)
- International NIMD Forum'97, Minamata, Kumamoto, JAPAN (Jul. 1997)
- SCOPE Workshop on Mercury Pollution in Asia, Changchun, Jilin, CHINA (Sep. 1997)
- International Workshop on Health and Environmental Effects of Mercury Due to Mining Operations, Manila, PHILIPPINES (Nov. 1997)
- Workshop on Scientific Issues Relevant to assessment of Health Effects from Exposure to Methylmercury, Raleigh, North Carolina, USA (Nov. 1998)
- The 5th International Conference on Mercury as a Global Pollutant, Rio de Janeiro, BRAZIL (May 1999)

Construction of a "Model Environmental City" based on the Experience of and Lessons from the Tragedy of Minamata Disease

Tomofumi Tanoue

Environmental Planning Section, Environmental Division, Minamata City Government

Minamata City has experienced suffering beyond description from a disease which came to be known as "Minamata Disease". Many years have passed since the official recognition of Minamata disease in 1956. However, our community has only just begun to turn the experience of Minamata Disease into a public lesson.

The occurrence of Minamata disease during the post-war economic revival, where the victims and perpetrators lived together in the same enterprise-supported small town, not only caused the destruction of the regions environmental well-being and many lives but, it also negatively effected the relations between the residents in Minamata City.

The residents of Minamata City have confronted Minamata Disease head-on. They did not underestimate the sufferings of the disease, but instead they learned to appreciate the valuable lessons to be learned from their experiences. The residents, together with the industry and municipal administrations of Minamata City, have been working together to establish a society that coexists in harmony with the environment.

As a result of the experience of Minamata Disease, Minamata City will be very much environmentally-conscious from now on. We are aiming to achieve the international standard for a "Model Environmental City", building a resource-recycling lifestyle that does not cause disruption of the environment, but instead promotes measures for environmental awareness and conservation. In this age of global scale environmental awareness, we will share with the world the plights and sufferings of the victims to prevent the tragic occurrence of Minamata Disease elsewhere. And it would be our pleasure for Minamata City's concerted efforts to create a Model Environmental City that would spread beyond its, contributing to the conservation and improvement of the global environment.

"Environmental City, Minamata"

Creation of an environmental model city, utilizing the experience of and lessons from Minamata disease

Minamata City Environmental ISO 14001

Outline of Minamata City

Located in the southernmost area of Kumamoto Prefecture

Close to the border with Kagoshima Prefecture

Area: 162.87 km^2

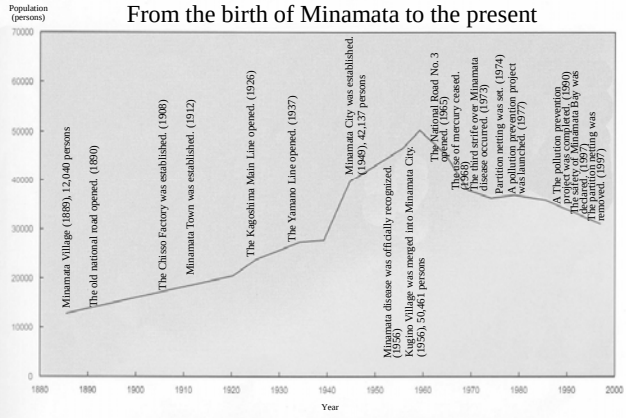
Population: 29,418

Number of households: 12,462

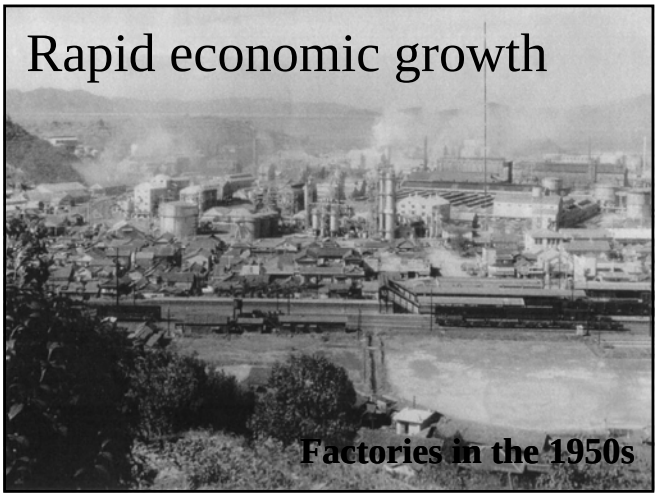
As of the end of August 2006

History of Minamata City

From the birth of Minamata to the present



Rapid economic growth



Factories in the 1950s

Minamata disease

- Officially recognized on May 1, 1956
- Number of officially designated victims: 2,268
  [Number of the dead included in the above: 1,629]
- Number of recipients of medical services: 10,353
  As of the end of July 2007; excluding the victims of Niigata Minamata disease

Photos by Jin Akutagawa 1979-1991

50 years after the official recognition of Minamata disease

After the decision of the Supreme Court in relation to the Kansai suit

Number of applicants for designation:
More than 5,000

Number of applicants for the Health Handbook:
More than 6,000

Impacts of Minamata disease

Impacts on victims who lost life or fell ill, and Minamata citizens

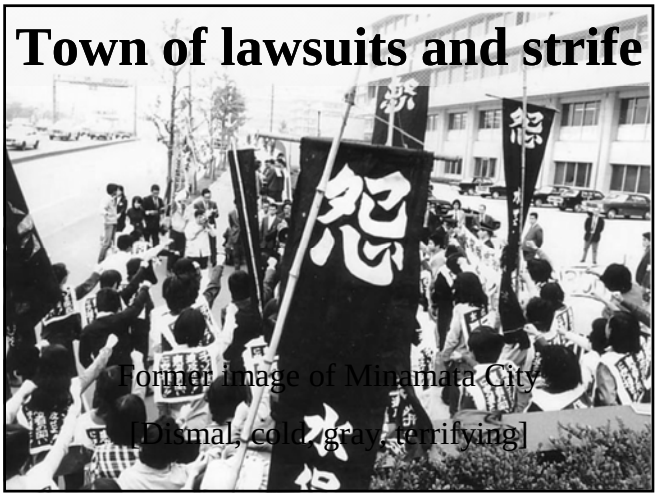
Commodities do not sell.
People do not come.
Difficult to get married
Difficult to be employed
Hesitate to say, "I am from Minamata"

→ Disruption of the community
Citizens ⇔ Victims

↓

Sluggish local economy

Town of lawsuits and strife

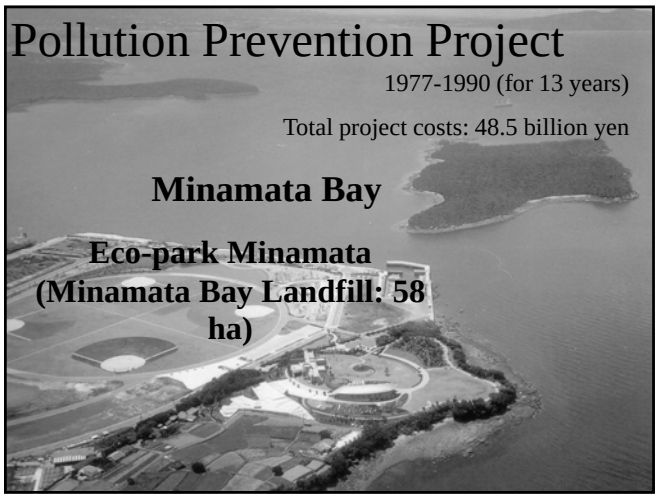


Former image of Minamata City
[Dismal, cold, gray, terrifying]

Pollution Prevention Project

1977-1990 (for 13 years)

Total project costs: 48.5 billion yen



Minamata Bay

Eco-park Minamata (Minamata Bay Landfill: 58 ha)

Environmental Creative Minamata Project (1990-1998)

Restoration of the community, integration ⇒ *Moyainaoshi* (restoration of ties) ⇒ Partnership among residents

Community devastated by environmental pollution (Minamata disease is a negative legacy.)

↓

Regeneration of the community by restoring the environment (Minamata disease is regarded as a positive factor.)

Declaration of the creation of an environmental model city [November 14, 1992]

↓

Make good use of the lessons from Minamata disease.

↓

Don't allow the recurrence of disastrous pollution-caused diseases.

↓

Pay attention to water, food and waste.

↓

Fortune will offset misfortune.

Waste sorting collection

March 1993	Start in a model district
	Holding of explanatory meetings in the other districts
August 1993	Start in all the districts in the city (Sorting into 20 types)
	Municipal officials took charge of the collection. (For half a year)
April 2000	Containers and Packaging Recycling Law (Sorting into 23 types)
December 2002	Start of the sorting of garbage (Sorting into 24 types)
April 2003	Review of the sorting (Sorting into 21 types)
April 2004	Reuse of 0.9 L bottles for *shochu* (distilled liquor)
April 2005	Review of the sorting (Sorting into 22 types)

Waste sorting method

- **Waste collection stations are established at about 300 locations in the city.**
- **(One station for about 50 households)**
- **The residents take care of the stations.**
- **The recycling promoter recommended in the district and a person on duty for a month are responsible for the sorting.**
- **The municipality takes the charge of the collection and transportation of sorted waste.**

Division of roles between the citizens and the municipality

Recyclables (20 types)

For one hour a month (Container method)

Combustible waste and garbage

Collected twice a week

Districts where the waste is collected on Monday and Thursday

Districts where the waste is collected on Tuesday and Friday

* Waste plastics are collected on Wednesday.

Garbage is packed into the biodegradable plastic bags designated by the municipality.

High evaluation by the third party

All the citizens sort waste on their own initiative.

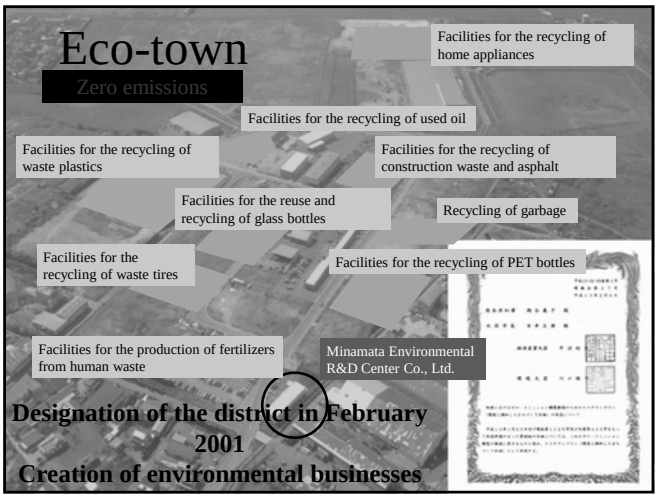
Lessons from waste sorting

Meeting around the stations

Communication through the sorting of waste

Prolongation of the life of landfill sites


Sources for continuation
Profit on sale 10,000,000 yen/year
Return to each district


Eco-town
Zero emissions
Facilities for the recycling of home appliances
Facilities for the recycling of used oil
Facilities for the recycling of waste plastics
Facilities for the recycling of construction waste and asphalt
Facilities for the reuse and recycling of glass bottles
Recycling of garbage
Facilities for the recycling of waste tires
Facilities for the recycling of PET bottles
Facilities for the production of fertilizers from human waste
Minamata Environmental R&D Center Co., Ltd.
Designation of the district in February 2001
Creation of environmental businesses


Reduction in the volume of waste
「ごみ減量」目指して
女性3500人スクラム
水俣市 連絡会議結成し啓発へ
Women's Waste Reduction group

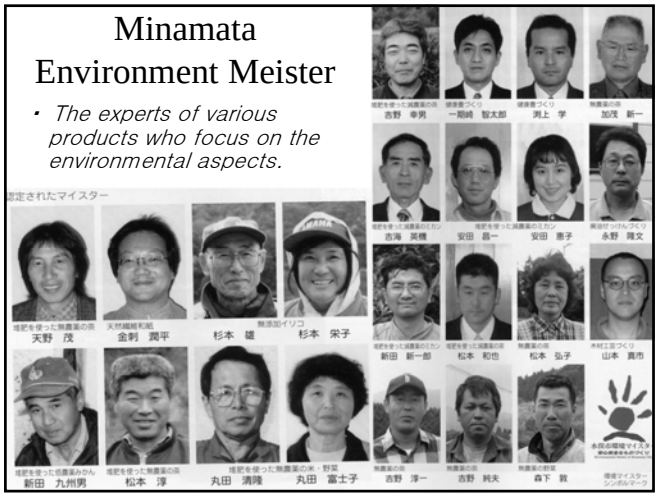

Signing ceremony for the agreement concerning the abolition of plastic trays for food
Shops
Mayor
Chairperson of the city assembly
Women's Waste Reduction Group
Conclusion of the agreement on the abolition of plastic trays for 76 food items

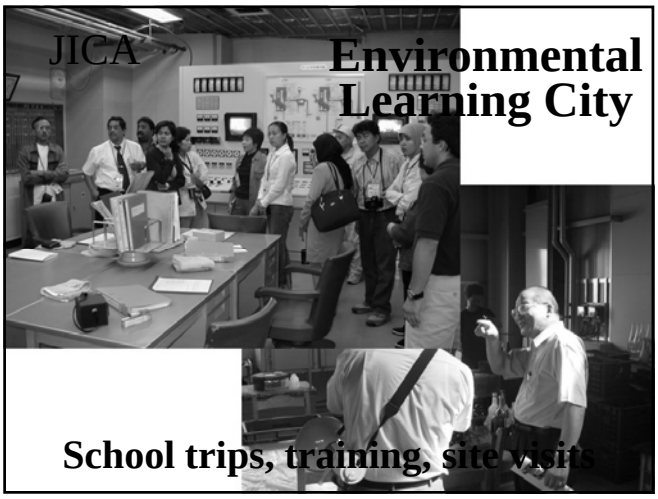

Awarding of the Grand Prix for Cheerful Companions for Waste Disposal

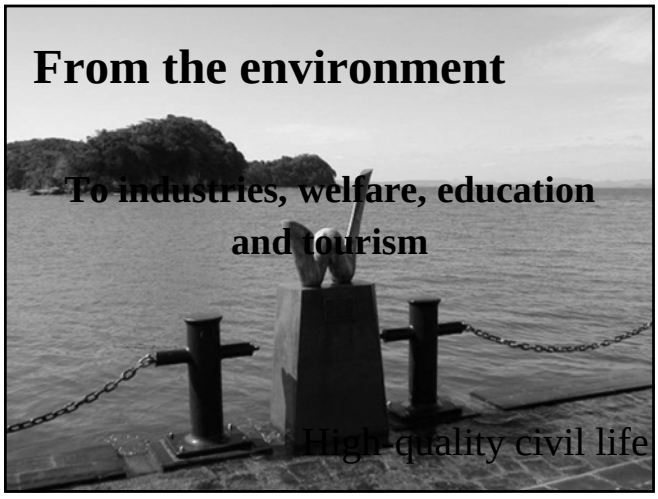

Regional Environmental Agreement
頭石地区環境協定
To protect the nature and living environment within their own region.

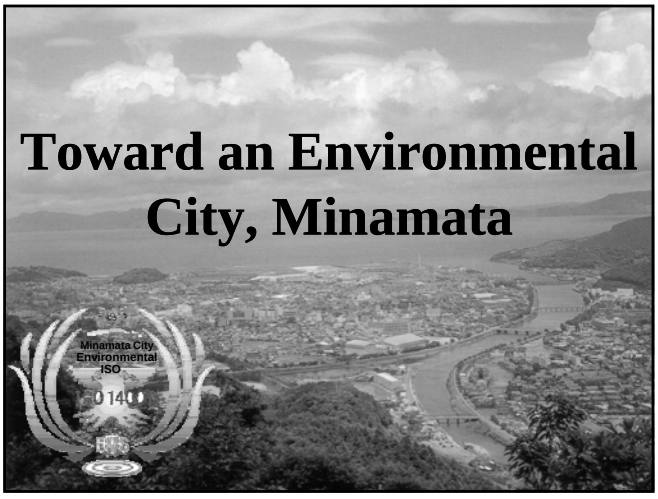
Minamata Environment Meister

- *The experts of various products who focus on the environmental aspects.*










Yunotsuru hot springs
Yunoko hot springs
Thank you for your attention. - End -

Treatment Techniques of Soil Which Was Contaminated by Mercury in Japan

Akito Matsuyama

Risk Evaluation Section, Department of Epidemiology, National Institute for Minamata Disease

Recently, anthropogenic pollution of soil which was contaminated by VOC and heavy metals etc in industrial area is very big serious problem in Japan. Based on the social requirement and environmental facts, Soil Contamination Countermeasures Law which includes a lot of environmental regulatory standard values of toxic substances was established by ministry of the environment at 2003. Basically, there are 25 regulatory standard values on toxic substances including heavy metals in this law. Especially, a regulatory standard value of mercury is most hard in heavy metals species of this law, a regulatory standard value of total mercury concentration in soil is 15ppm and soluble mercury in soil is 0.5ppb. Then until now, obviously cases of polluted soil by heavy metals are increasing (1991-2006). Then the ratio of mercury pollution cases in whole heavy metals pollutions were almost 10%. To improve the soil which was polluted by mercury, there are a lot of treatment techniques in Japan. Currently, perfectly the excavation and transfer by using special technique is recognized as the most useful technique for improving of soil which was contaminated by mercury etc. Because this technique held 62% in the treatment techniques which were used in order to improve heavy metals pollution in Japan. In general, Incineration and Soil washing are evaluated that both techniques are very effective as a purification technology. Basically, since these techniques can remove the heavy metals from contaminated soil, these are very important as a remediation technology for environment. However, the amounts of treatment cases by using these purification techniques are very scarcely in Japan. Ratio of these technologies in whole treatment cases is almost 27% in Japan. On the other hand, from a practical viewpoint of scientific technology, the excavation and transfer is thought to be not a remediation technology. Because, if it is used as treatment technique, soil is treated by using solidification etc, and then it is buried in Final Landfill Site for isolation. Therefore, it can't be reused forever. However, from a practical viewpoint of treatment cost, in comparison with other treatment technique, case of excavation and transfer, the treatment cost is almost one-thirds. Therefore, the excavation and transfer was considered to be reasonable as a basic treatment technique for improving of soils which were polluted by heavy metals (mercury etc) in Japan.

However, to remove mercury from soil or sediment which was polluted by mercury, NIMD has developed a new treatment technique which is called the low temperature thermal treatment. In comparison with Incineration, because our heating temperature by using special additive (FeS) is set less than half of Incineration (our heating temperature 300°C<), the treatment cost is cheaper than Incineration. Moreover, it can remove mercury more than 95% from the soil or sediment which was polluted by mercury within almost 1hour heating.

Treatment techniques of soil which was contaminated by mercury in Japan

Akito Matsuyama Ph.D.
Department of Epidemiology Science
NIMD forum 2008 March

1 1

1. Soil Contamination Countermeasures Law

To prevent a contamination of soil by toxic substances, this law was established by ministry of the environment at 2002.
Case of this law, not only environmental regulatory standard value but also survey method of each category on toxic substances were decided.

Environmental regulatory standards are decided about 25 species of toxic substances (Heavy metals and VOC's etc)

Case of heavy metals, there are 6 environmental regulatory standards values in this law (Cd, Hg, Cr, Se, Pb, As etc).
Especially, mercury is severe as follows.

<Soil>
Total mercury concentration 15ppm
Soluble total mercury concentration 0.5ppb
Soluble alkylmercury concentration must not be detected

2 2

The flow of countermeasures for mercury contamination of soil in Japan

If we found a soil which was contaminated by mercury !

<First step >
To choose a reasonable countermeasures for soil which was contaminated by mercury, we have to do an environmental survey based on the Soil Contamination Countermeasures Law .
<For instance, as follows>
- Health information of habitants in the contaminated area
- Resource information of the mercury contamination
- History information of mercury contamination
- Topographical distribution of mercury concentration in the contaminated area
- Quality of ground water in the area which was contaminated by mercury

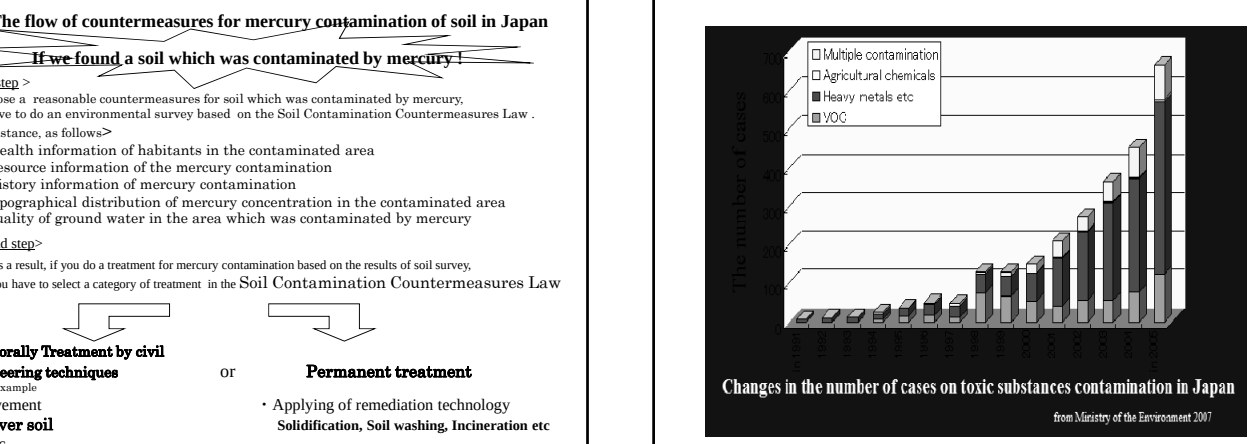
<Second step>
- As a result, if you do a treatment for mercury contamination based on the results of soil survey, you have to select a category of treatment in the Soil Contamination Countermeasures Law

Temporally Treatment by civil engineering techniques
For example
- pavement
- **cover soil**
- etc

or

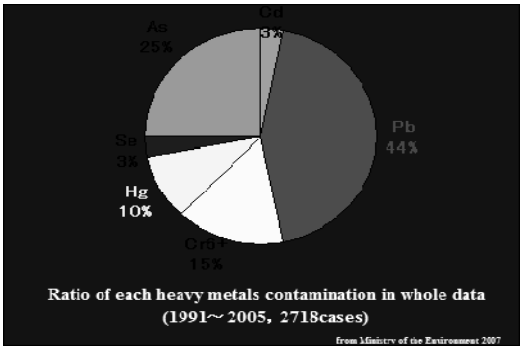
Permanent treatment
- Applying of remediation technology
  Solidification, Soil washing, Incineration etc

3 3



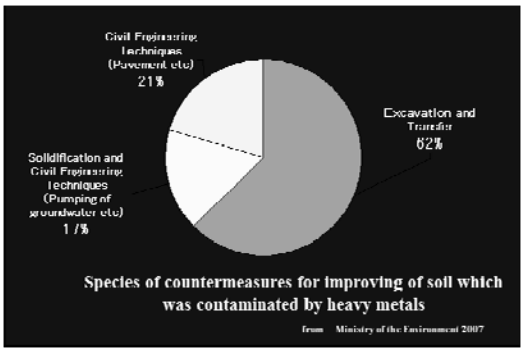
Changes in the number of cases on toxic substances contamination in Japan
from Ministry of the Environment 2007

4 4



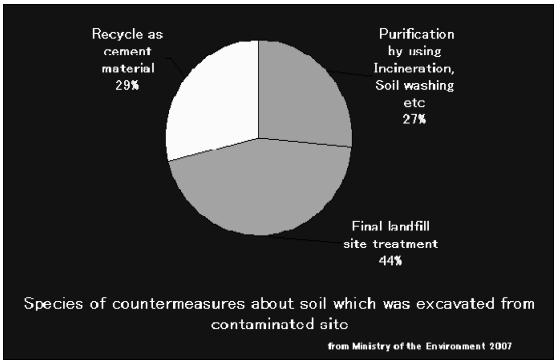
Ratio of each heavy metals contamination in whole data (1991~ 2005, 2718cases)
from Ministry of the Environment 2007

5 5



Species of countermeasures for improving of soil which was contaminated by heavy metals
from Ministry of the Environment 2007

6 6



Species of countermeasures about soil which was excavated from contaminated site

from Ministry of the Environment 2007

7 7

<Purpose of our study>

We think the soil which was contaminated by heavy metals (mercury etc) should be purified by using remediation techniques (Incineration ,Soil washing etc) as soil.

⇒ However, almost contaminated soils aren't reused as soil.

Because, In general ,there seems to be several drawbacks in remediation techniques as follows.

- Treatment cost is higher than other techniques
- Treatment term is longer than other techniques
- Moreover, if we applied these remediation techniques to contaminated soil, important functions of soil as a basis of plant are almost changed.

These remediation techniques hadn't been applied to contaminated soil in Japan .

Therefore, the purpose of our study is to overcome these drawbacks, and we had been to develop a more suitable remediation technology

Low temperature thermal treatment

8 8

■ The outline of our new remediation technique

- Our new technique is belong to thermal desorption in heat treatment.
- Our technique isn't Incineration
- Treatment target of heavy metals as a countermeasure by using our technique is mercury which include organic mercury.

Comparison of between incineration and thermal desorption (Low temperature thermal treatment, NIMD) about outline of these treatments

	Thermal treatment	
	Incinaration	Thermal desorption(NIMD)
Heating temperature	600-900℃ or more	250-300℃
Additives	—	FeS
Removal percentage	95% or more	95% or more

9 9

Comparison about characteristics of thermal treatments

	Thermal treatment	
〈Items〉	Incinaration	Thermal desorption(NIMD)
operation	complication	Simple
Soil conditions (after treatment)	red color and broken brick	brown color and almost the same
costs (include civil engeneering fee,in Japan)	700$ to 1000$/1cubic meters	350$ to 450$/1cubic meters

- Soil has many important functions as a basis of plants or micro-organisms.
- In case of Incineration, the important functions in soil are lost by high temperature heati
- However, since the heating temperature of our method is lower than incineration, the important functions of soil are kept after the heat treatment.

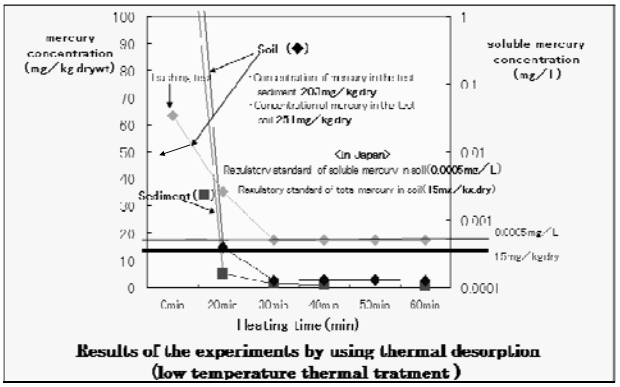
10 10

Condition of our experiment using test plant in NIMD

Heating temperature	250 -300℃
Heating time	continuously 1hour
Mercury concentration in the test material	soil 251mg/kg.dry wt
	Minamata bay sediment 201.3mg/kg.dry wt
The amount of test materials for experiment	25kg.wet wt/one time
The amount of additive(FeS)	1% of test material weight
Pressure setting	Atmospheric pressure
Method of heating	Rotaly kiln

11 11

Our test plant



Results of the experiments by using thermal desorption (low temperature thermal tratment)

12 12

Level of Dioxins in the exhaust gas from test plant which is bigger than our test plant

- Dioxins level‥‥‥ 0.38ng-TEQ/m³N
  Treatment ability of our test plant is 0.5t/h

◎ Japanese regulation value of dioxins 5ng-TEQ/m³ N
(This regulation value is applied to a Incineration plant which can treat under 2t/h as the amount of treatment)

13 13

- The problem in the future

We aren't able to get an experience of real scale treatment by using this technique to soil which was contaminated by mercury yet.

To solve our conditions in the near future

・Reducing of total treatment cost
・ we must get good stability of the processing

To supply a more suitable technique to society, we have to continue development and improvement about our technology

14 14

Zero Mercury Emission Strategy in Sweden

Lars D. Hylander[a]***,** Markus Meili[b], and Kjell Johansson[c]

[a] Dept. of Earth Sciences, Uppsala University, Villavägen 16, S-752 36 Uppsala, Sweden; [b] Stockholm University, Dept. of Applied Environmental Science (ITM), Frescativ. 50, S-106 91 Stockholm, Sweden; [c] Dept. of Environmental Assessment, Swedish University of Agricultural Sci. Box 7050, S-750 07 Uppsala; alternatively Swedish Swedish Environmental Protection Agency, S-106 48 Stockholm, Sweden
** Corresponding author phone: +46--(0)18-471 22 65; Fax: +46--(0)18-55 11 24;*
E-mail: Lars.Hylander@hyd.uu.se

Mercury (Hg) is of world-wide concern because of its toxicity not only to humans but also to other higher forms of life as well as microorganisms in natural environments. Methyl-Hg is the species of particular concern for birds, fish and mammals, where biomagnification in long food chains results in hazardous exposure of top predators including humans. Elemental Hg is transformed to methyl-Hg in nature by processes difficult to control, and any emission of inorganic Hg will ultimately result in increased levels of methyl-Hg in our environment. Restricting anthropogenic emissions of Hg is thus a priority for counteracting an increase of methyl-Hg levels in biota. To eliminate the sources is a cost-effective way of eliminating related emissions.

There are three primary sources of anthropogenic Hg emissions: 1.) combustion of fossil fuels; 2.) dedicated mining of Hg; and 3.) refining processes and mining of minerals for recovering of other elements than Hg. Mercury produced by mining and refining is used in a wide variety of products such as thermometers, dental amalgam, lamps, and batteries, resulting in Hg emissions at production, usage, and disposal.

Swedish authorities were first to act by enforcing nationwide legislation against the use of Hg, to avoid tragedies such as those in Minamata, Japan. Consequently, seed dressing with methyl-Hg was prohibited in 1966, and fenyl-Hg in slimicides was prohibited in 1967. Total emissions of Hg from Swedish chlor-alkali plants to air and waters were reduced from more than 30 t per year in the 1950's and 1960's to less than 0.1 t nowadays. Sale of clinical thermometers containing Hg is prohibited since 1992, and Hg exports are banned since 1997. A general ban on the use of Hg in processes and products is presently considered by the government. From the ban there will be exceptions only where Hg free alternatives still have a limited market share, such as energy-efficient lamps.

Recycling of Hg is discouraged in Sweden, since continued use of Hg-containing products inevitably results in losses of Hg to air, soil and water, thus adding to the risks of human exposure. Mercury-containing equipments, products, and waste are instead collected for permanent disposal in a safe deep-bedrock repository with minimal losses. This has by Swedish authorities been considered as the only feasible solution to obtain zero Hg emissions from the Swedish technosphere. Further information may be obtained from the Swedish Chemicals Agency (www.kemi.se) and the Swedish Environmental Protection Agency (www.naturvardsverket.se).

Zero mercury emission strategy in Sweden

Thursday 27 March 2008, 11:30-12:15.

Lars D. Hylander [a], **Markus Meili** [b], **and Kjell Johansson** [c]

a) Uppsala University, Department of Earth Sciences Air, Water and Landscape Science **E-mail: Lars.Hylander@hyd.uu.se**

b) Stockholm University, Dept. of Applied Environmental Science (ITM)

c) Swedish University of Agricultural Sci.; alternatively Swedish Environmental Protection Agency

Foto: Eugene Smith

Disposition incl. background and fundamentals

* Characteristic features of Hg
* Exposure via the environment
* The origin: metal mines and fossil fuels
* Use of Hg (chlor-alkali, gold mining, electric, dental)
* Actions to reduce problems
* Conclusions

Lars.Hylander@hyd.uu.SE

Miraculous Mercury

”All materia´s mother.”

Could gold be produced from Hg?

Hg Hg

Lars.Hylander@hyd.uu.SE

Physical properties

	Ag	Hg	Au	Pb	Cd	Fe	Al
•Melting point (oC)	962	- 39	1065	328	321	1535	660
•Boiling point (oC)	2212	357	2700	1740	765	3000	2467
•Density (kg/L)	10	14	19	11	9	8	2.7
•Price (skr/kg)	3800*	107**	166 000*	7+	5-7	6+	15+

* www.Boliden.com accessed 21 April, 2006, ** Hayes, 2004

+ http://minerals.usgs.gov/minerals/pubs/commodity/ 1998, 2006

Lars.Hylander@hyd.uu.SE

Mercury (Hg) characteristica

(Guimarães et al., 1995; Nationalencyklopedin, 1992; UNEP, 2002 and ref. therein)

Element Nr 80 (after gold) in the metal group of the periodic table

Atomic weight, average 200.59

Stable isotopes: (196)198-204

Radio isotopes: e.g. ^{203}Hg, half time 47 days

Hg^0 stays ~1 year in the atmosphere → **4 turns around the globe**

High vapour pressure so evaporates easily.

Lars.Hylander@hyd.uu.SE

Species

Metallic or elemental Hg (Hg^0)

Inorganic Hg e.g. Hg(I), Hg(II) also Hg^{2+} & salts

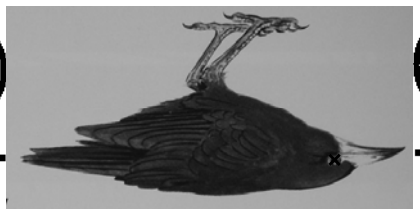
Organic Hg when combined with C. Notably methylmercury (MeHg or CH_3Hg^+)

Continous conversions in nature and society!

(UNEP Chemicals. Global Mercury Assessment. Report. 2002. http://www.chem.unep.ch/mercury/)

Lars.Hylander@hyd.uu.SE

Could Mercury really be deadly?



1950

Karl Borg found high contents of Hg in a dead crow (rook; *Corvus frugilegus*, from Örtofta, Scania)

Lars.Hylander@hyd.UU.SE

Toxicity

Metallic Hg:

”Harmless” if swallowed occassionally.

Vapour is a serious neurotoxicant, which passes the blood-brain barrier.

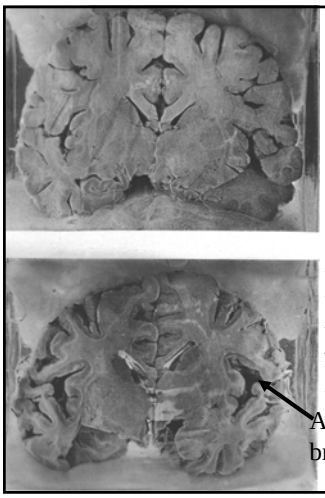
Inorganic Hg e.g. Hg^{2+} & salts

Serious neurotoxicants.

Methylmercury

A serious neurotoxicant also at low exposure.
Passes both the blood-brain and placental barriers.
Possibly carcinogenic and cardio-vascular effects.

Lars.Hylander@hyd.UU.SE



”Tom i huvet”
”Empty head/
Vacant mind”

Healthy brain.

Brain from a person with Minamata disease.

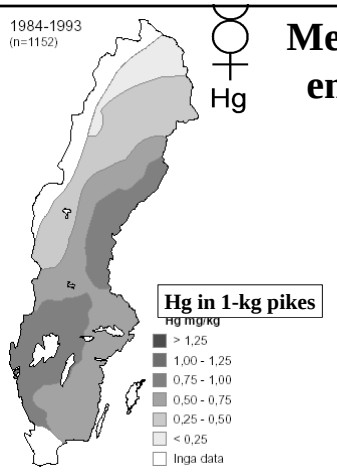
An empty space in a shrinking brain due to necros/small neurons

Lars.Hylander@hyd.UU.SE

Kids and foetus are most vulnerable to Hg

Foto: Kristoffer Hylander

Mercury in the environment



METALLER I STAD OCH LAND
Nv Rapport 5184. 2002, som citerar Andersson och Lundberg, 1995.

Lars.Hylander@hyd.UU.SE

Misunderstanding

”Hg emitted into the environment can be treated later on.”

The polluted Örserumsviken the Baltic Sea, Västervik, in the 1960’s.

Lars.Hylander@hyd.UU.SE

Hg

4 decades later and 750 kg less Hg

Foto: Kenneth Hardy Axelsson, Fotohuset AB i Västervik och Bertil Ljung.

Total cost: 15 millions US$ (115 millions skr) corresponding to 20 000 US$/kg Hg (150 000 skr/kg) more than 250 MAN YEN/kg

Lars.Hylander@hyd.UU.SE

Hg

50 years since Minamata disease was officially reported (1956).

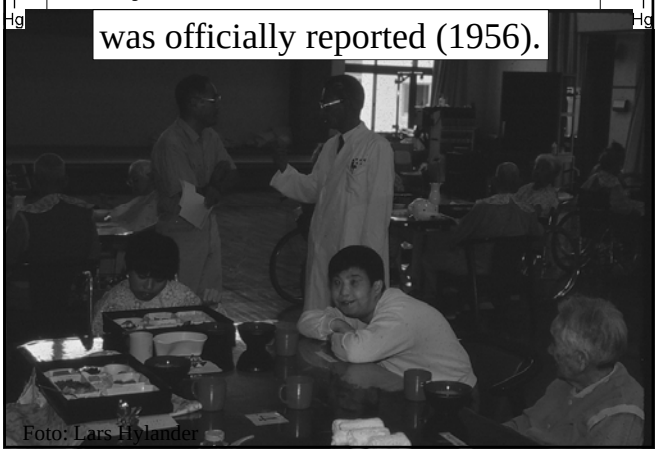
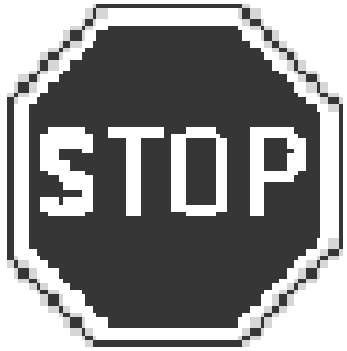


Foto: Lars Hylander

Hg



continued use of Hg!

Paying too little may cost too much!

Lars.Hylander@hyd.UU.SE

http://www.mayasa.es/

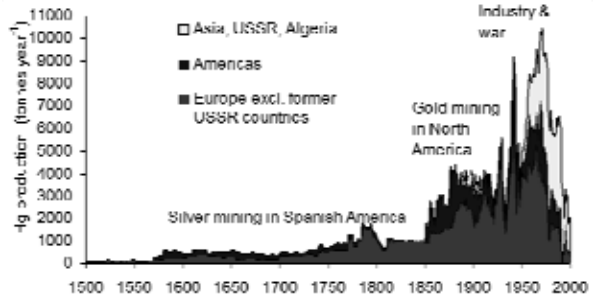
Ltd State company.
350 employed
in 5 sectors

The origin -- mine production of Hg and as a byproduct from other metals and from fossil fuels.

Lars.Hylander@hyd.UU.SE

Hg

Note the complementary qualities of fulminate (in explosives) and sublimate (desinfectant for wounds)



Global production=consumption of virgin Hg.

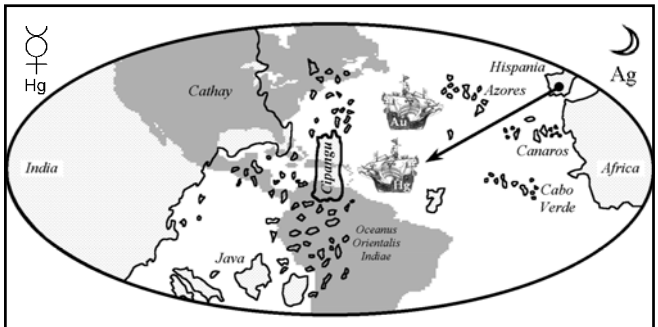
Hylander & Meili, 2003. *Sci. Total Environ.*

Lars.Hylander@hyd.uu.se

Hg Ag

Columbus' assumptions about the location of east Asia and his venture in 1492 of sailing west to Japan (Cipangu), “the country glimmering in gold” east of China (Cathay)…

Lars.Hylander@hyd.UU.SE



resulted in an exchange of Hg for gold and silver from the New World, which entailed that mercury became an early global pollutant.

(Hylander & Meili, 2003. *Sci. Total Environ.)*

Lars.Hylander@hyd.UU.SE

Hg

Stop mining of Hg!

Mining of mercury is out of senses!

Hg

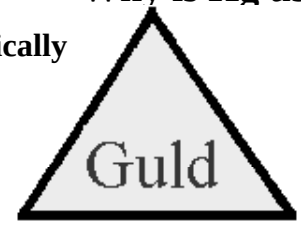
ARTISANAL GOLDMINING is considered in Sweden's mercury strategy

* now the largest? consumer of mined Hg
* taking place in countries with no or poor health and environmental protection
* resulting in large emissions of Hg to air, water and soil
* Swedes do not accept that Hg replaced in Sweden is being exported to countries with less protection of health and environment

Lars.Hylander@hyd.UU.SE

Hg

Why is Hg used?



Technically easy

Mix, stirr, wash, and burn!

Economically profitable

1 g Au buys nearly 1 kg Hg

Physically possible

Melting point –39 °C (cf. Au 1065)

"Dissolving" gold

Boiling point 357 °C (cf. Au 3700)

Lars.Hylander@hyd.UU.SE

Hg

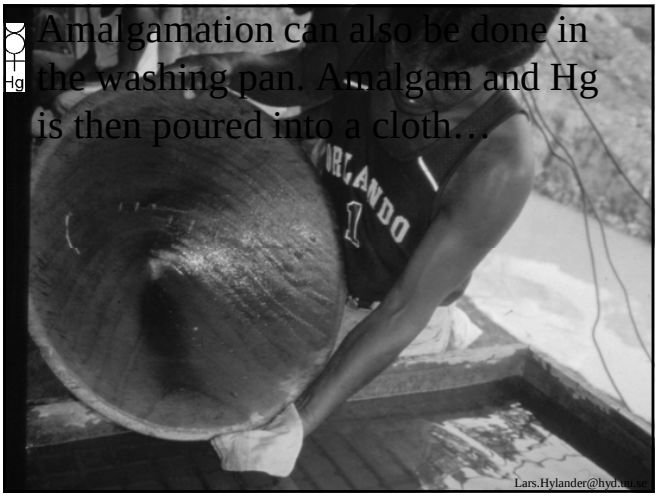
Goldminer in Amazonas

using the amalgamation method by massaging the milled ore into Hg covered sheets with his bare hands.

Lars.Hylander@hyd.UU.SE

Hg

Amalgamation can also be done in the washing pan. Amalgam and Hg is then poured into a cloth…



Lars.Hylander@hyd.UU.SE

Hg

and excess Hg squeezed out.

Foto: Lars.Hylander

Lars.Hylander@hyd.UU.SE

Hg

Gold amalgam is put on a spade and heated by a gas burner.

Mercury evaporates, leaving pure gold behind.

Lars.Hylander@hyd.UU.SE

Hg

Protect the men…

Foto: Lars.Hylander

Lars.Hylander@hyd.UU.SE

Hg

Options to combat Hg emissions from amalgamation

Reduce the demand for gold.

Reduce the availability of Hg,
e.g. by restricting International Hg trade.

Lars.Hylander@hyd.UU.SE

Use mercury free gold mining methods

Lawanit

Cleangold sluice

Carbon in pulp, CIP Cyanidation

Lars.Hylander@hyd.uu.se

Ag

Hg

Amalgamation leaves half of the gold behind!

Hylander, L.D., Plath, E., Miranda, C.R., Lücke, S., Öhlander, J., & Rivera, A.T.F. 2007. Comparison of different gold recovery methods with regard to pollution control and efficiency. *CLEAN - Soil, Air, Water 35(1)*:52-61.

Lars.Hylander@hyd.UU.SE

The Kimberley Process

an International certification system for raw diamonds
(Sources: Ralph Hazleton, a Research Associate at the Partnership Africa Canada Human Security and Diamonds Project, and http://pacweb.org/e/)

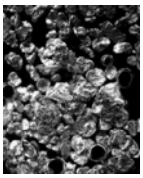
with the aim to stop trading war diamonds.

War diamonds are financing the wars in Africa in e.g. Angola, Liberia, Congo, Sierra Leone,

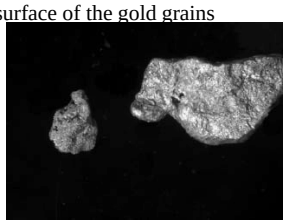
Lars.Hylander@hyd.UU.SE

Gold recovered without Hg or cyanide could also be certified

by studying the surface of the gold grains



Beach gold from Lincoln City, Oregon.



Gold from Sharp's Creek, Bohemia Mining Dist., Oregon, with historic gold mining.

Left gold grain with amalgamated surface.

Right gold grain with a dark hollow.

Hylander, L. D. & Plath, D. 2006. Microscopy and certification as tools for environmentally benign, mercury-free small-scale gold mining. *Sci. Total Environ. 368*: 371-383.
Hylander, L.D., Plath, D., Miranda, C.R., Lücke, S., Öhlander, J., & Rivera, A.T.F. 2007. Comparison of different gold recovery methods with regard to pollution control and efficiency. CLEAN - Soil, Air, Water 35(1):52-61.

Lars.Hylander@hyd.UU.SE

Best Available Technology
for production of chlorine and soda
is Hg free
and uses less energy
than Hg cells do.

Membranes are
BAT

Lars.Hylander@hyd.UU.SE

European chlor-alkali plants have 15000 tonnes Hg

Photo courtesy: Akzo Nobel

Where does MAYASA sell this Hg for
"legitimate uses"?

Lars.Hylander@hyd.UU.SE

Surprise, surprise?

Hg from Spain,
the US, Russia,
China, Algeria
found in
the Philippines,
used for gold mining.

Lars.Hylander@hyd.uu.se

A shift in paradigm from a resource to refuse.

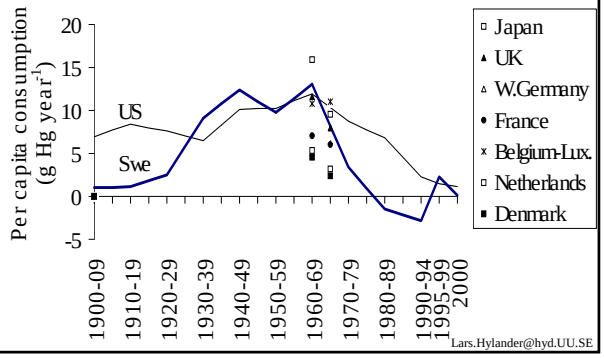
In which cavities should we put Hg waste?

Teckning: Monica Kauppi, Heavy Metal Bulletin

Use of Hg

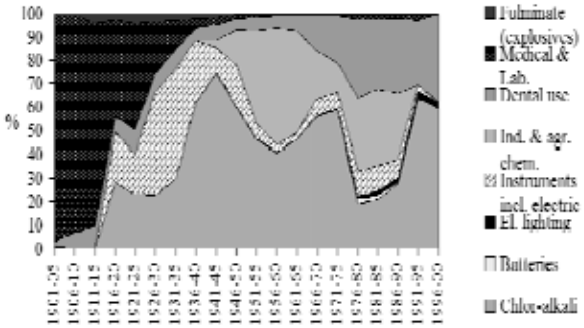
Nationalencyklopedin, 2005

Per capita consumption of primary Hg peaked in the 1960's.



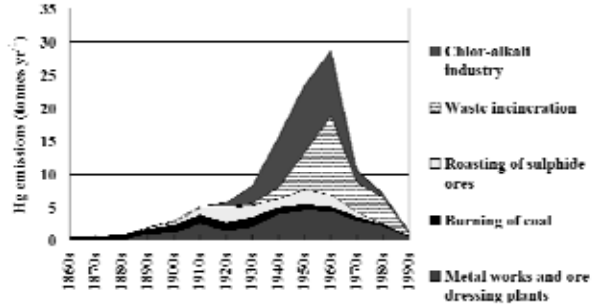
Lars.Hylander@hyd.UU.SE

Consumption pattern of primary plus recycled Hg in Sweden



Lars.Hylander@hyd.UU.SE

Emissions were LARGE in Sweden



Anthropogenic point source emissions of Hg to the atmosphere in Sweden 1860 – 2000.

(Details in Hylander. 2001. *Water, Air Soil Pollut.*)

Lars.Hylander@hyd.UU.SE

The large consumption of Hg has resulted in large stocks of Hg in products still in use.

Examples:

Chemical industry

Teeth

El- industry (switches, fluorescent tubes, car bulbs, PC:s)

Lars.Hylander@hyd.UU.SE

Stocks of Hg *(tonnes)* used in society

	Sweden		EU + EFTA
Usage	**1992**	**2002**	**2002**
Chlor-alkali factories	400	400	12 000 - 15 000
Teeth	40-60	30-50	1 300 - 2 200 *
Electrical app. & instr.	10-30	3-5	430 – 1 300 *
Thermometers	5-10	2.5-5	215 - 430 *
Dry and button cells	3-5	-	-
Laboratory chemicals	2-4	1	90 - 180 *
Fluorescent tubes	~0.6	1	~60 *
Sum	**460-500**	**438-462**	**14 095 - 19 170**

* If per capita amalgam fillings and use in the other countries are in parity with Sweden before Hg laws were implemented.

Sources: SOU 2001:58; Lindley, 1997; Naturvårdsverket, 1993; Rein and Hylander, 2000; SCB, 2002

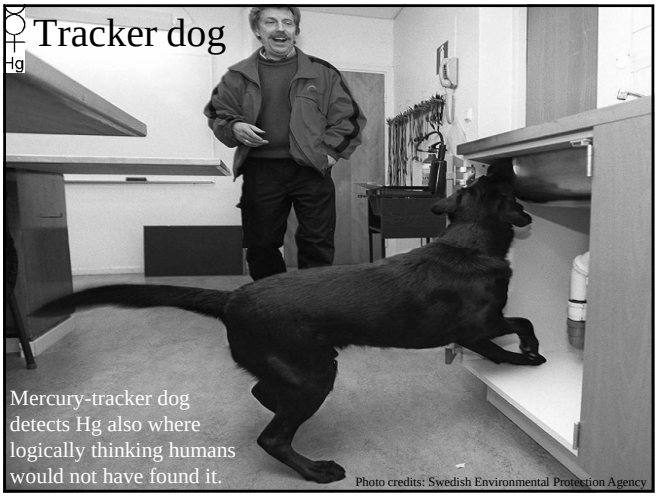
Lars.Hylander@hyd.UU.SE

Hg phase out (Rein & Hylander. 2000. *Regional Environ. Change J.*)

Quantities and cost for Hg collected in different Hg collecting campaigns in Sweden.

Campaign and region	Year	Received Hg (kg)	Cost (US$ kg^{-1})	Observations
Return of thermometers				
Stockholm	1992	380	1 200	190 000 thermometers
Malmö	1992	121	1 150	60 000 thermometers
38 smaller municipalities	1994/96	190	950	
Schools and universities				
Skolkem, Gothenburg	1996	190	150	
Mercury 97, all Sweden	1997	1 700	70	Another 300 kg Hg reg.
Mercurius 98, all Sweden	1998/99	1 300	400	Another 350 kg Hg reg.
Other school projects	1995/96	80	250	
Industry and housing				
"Älvsborg free from Hg"	1995/96	630	150	Another 45 kg Hg reg.
Landskrona, Vetlanda, Östersund	1995/96	200	400	Another 38 kg Hg reg.
Inventories in Örebro, Gothenburg, Stockholm, Värmland, Västmanland	1998/99	1 500 - 2 000	240 - 180	Another 1 500 kg Hg registered
"Hg search", all Sweden	1999		--	1 300 kg registered
Total		6 291-6 791		**Hg detectives**

Tracker dog

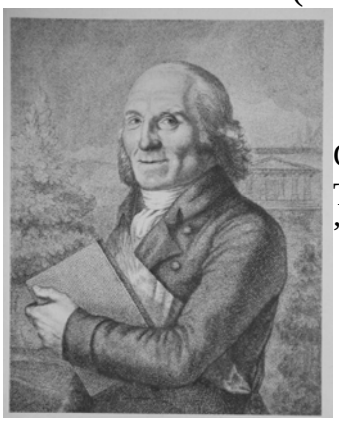


Mercury-tracker dog detects Hg also where logically thinking humans would not have found it.

Photo credits: Swedish Environmental Protection Agency

Carl von Linné, professor at Uppsala University.
We celebrate his 300 year anniversary this year.
He introduced mercury for
medical treatment in Sweden –
it took three centuries to phase out the use!

DARE DESU KA? (Who is this?)



Carl Petter THUNBERG
"Linné of Japan"

Portrait at:
Evolutionary museum,
Uppsala university

False beauty.

Photo: ALEXANDER LINDER

Ala Lombolo, a lake in Sweden,
which must be restaurated because of 200 kg
mercury emitted from a dental clinic and a laboratory.

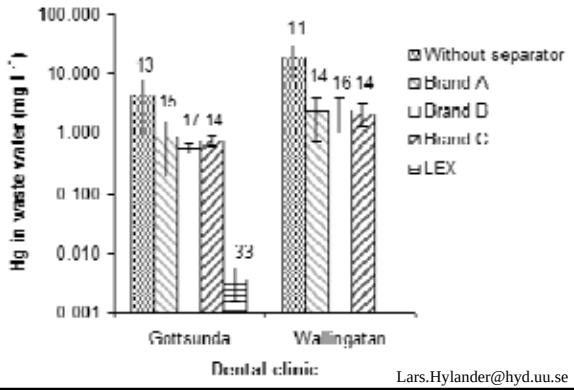
Lars.Hylander@hyd.uu.se

Amalgam separators, cheap but not efficient

Hylander, L. D., Lindvall, A., Uhrberg, R., Gahnberg, L., & Lindh, U. 2006. Mercury recovery in situ of four different dental amalgam separators. Sci. Total Environ. 366:320– 336

Lars.Hylander@hyd.uu.se

Mercury concentration in untreated wastewater and after four amalgam separators (average and 95 % confidence interval)
Logarithmic scale. Numbers indicate *N* (sampled days).



Lars.Hylander@hyd.uu.se

Conclusions

Hg emissions originating from placing, polishing or removing existing amalgam fillings, should be counteracted by complementing amalgam separators with the use of low-emission separators/filters
e.g. Capere dental filter
http://www.tekniskaverken.se/capere/capere_dentalfilter

Lars.Hylander@hyd.uu.se

Hindering recycling of nutrients

	As	Cd	Cu	Hg	Pb	Zn
[illegible]	–	2	[illegible]	2.5	[illegible]	[illegible]
[illegible]	[illegible]	5		2		
[illegible]	11	0.44	94	0.28	29	86
[illegible]	(0.4-70)	(0.03-2.53)	(4.4-170)	(<d.l.-5.30)	(3-185)	(39-422)
[illegible]	4.0	0.23	14.6 [1]		17.1	39
[illegible]	–	0.4	40	–	48	75
[illegible]		(0.5 %)	(3 %)		(0.8 %)	(27 %)

[illegible]

Lars.Hylander@hyd.UU.SE

Sweden (rikdagen) has adopted 16 national environmental goals, with the aim to get good living conditions.

Phasing out the use of Hg is part of the goal of an environment free of toxics.

Storvads badplats, aug. 2007
Foto: Lars.Hylander

How come that people care about the environment?

Photo:
Karl-Jan Erstad

Ever heard about **Nils** Holgersson flying on a goose over Sweden?

Hg

Key points in an action plan aiming at zero mercury emissions from anthropogenic sources

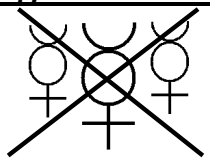
1. Phase out present use of Hg-containing products by prohibiting manufacturing and sales.

Adopt a plan for replacing Hg products in use.

Lars.Hylander@hyd.UU.SE

Hg

2. INFORM, Inform, inform that Hg is NOT necessary



Replace Hg thermometers by digital or alcohol thermometers.

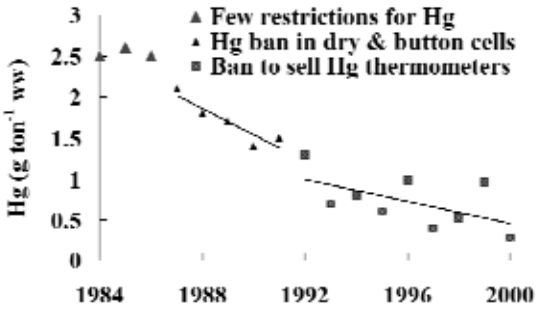
Replace Hg thermostats by digital or other Hg free ones.

Use Hg-free blood pressure manometers.
LED (light emitting diodes)

Lars.Hylander@hyd.UU.SE

Hg

3.Political actions are necessary

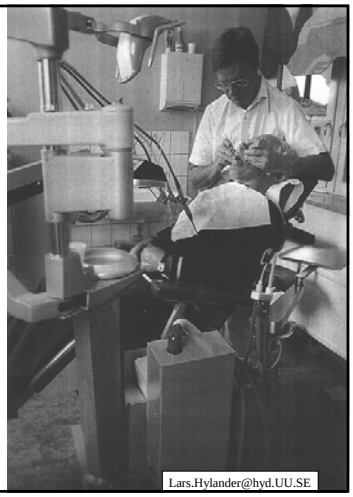


Mercury in waste in Uppsala, Sweden, related to legislation regarding products containing Hg.
(Hylander, et al., 2003. *Sci. Total Environ.)*

Lars.Hylander@hyd.UU.SE

Dental amalgam was not phased out with voluntary options (KEMI, 1998).

Therefor a general ban is now planned (with certain exceptions such as fluorescent lamps, button cells <1%, some chemical analyses).



Lars.Hylander@hyd.UU.SE

Hg

4. Separation of Hg in metallurgical smelters should continue!

Reduces atmospheric emissions.

Handle Hg produced properly (so called byproduct Hg).

Equally important to recover Hg from flue gases of power plants and waste incinerators.

Lars.Hylander@hyd.UU.SE

Hg

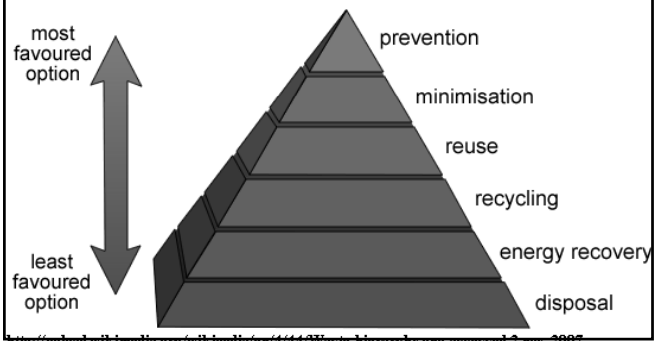
5. Investigate how to handle excess Hg from environmental and health points of view

~~**Recycling or reuse?**~~

Best solution:
Swedish Hg → Deep rock-bed deposition!

Lars.Hylander@hyd.UU.SE

Waste hierarchy



Hazardous waste landfills must be monitored forever!

Hg

Chigasaki, Japan. Foto: Lars Hylander

Turn of millennium, time to reverse the flow of Hg!

Send it back to Almadén.

Lars.Hylander@hyd.UU.SE

Hg

How to put Hg back into the mine?

In a safe and responsible way!

Make funds available for covering the costs based on PPP (Polluter Pays Principle)

Lars.Hylander@hyd.UU.SE

”Mile stones”

United Nations Environment Programme
environment for development

UNEP Chemicals. Global Mercury Assessment Report. 2002. http://www.chem.unep.ch/mercury/Report/

Convention on Long-Range Transboundary Air Pollution, United Nations Economic Commission for Europe, http://www.unece.org/env/lrtap
Heavy metal protocol ratified by >20 nations now (16 needed to enter into force, from 29/12 2003)

EU export ban for Hg. From 2011 for metallic Hg, compounds and goods containing Hg and already banned from sale in the EU. Storing excess mercury securely.
'polluter pays' principle
http://www.edie.net/news/news_story.asp?id=13226&channel=0

Lars.Hylander@hyd.UU.SE

What about Japan?

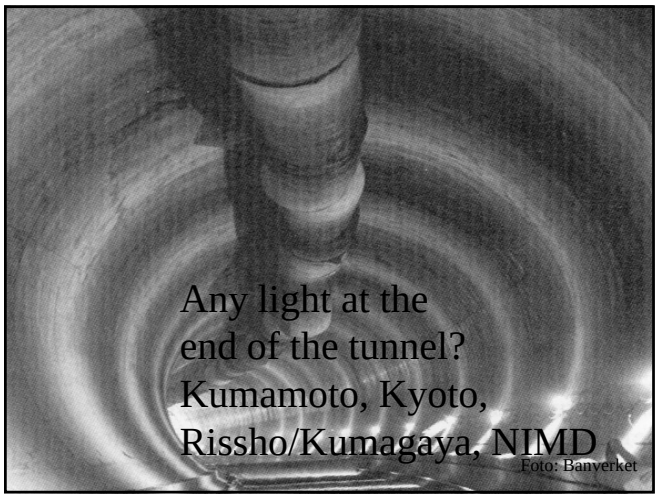
1950’s: ”No action”

1960’s: Stopping Hg emissions in Niigata and finally in Minamata

1970’s-90’s: Converting Hg cells in chlor-alkali plants to Hg free.
Restricting Hg in batteries.
World’s lowest limit for Hg in waste water sludge.

2000’s (until 2006): ”No action”
(e.g. no participation in Geneve to write the UNEP report Global Mercury Assessment,
no efforts to restrict global Hg trade,
Hg widely used in lamps and hospital equipments)

Lars.Hylander@hyd.UU.SE



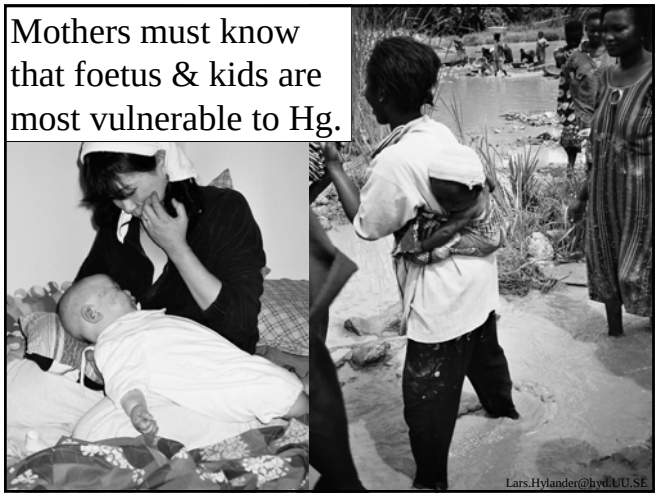
Conclusions I

None of the present uses of Hg can be motivated from an environmental point of view except for energy-saving lighting.

Most uses of Hg is not even economically motivated.

Lars.Hylander@hyd.UU.SE

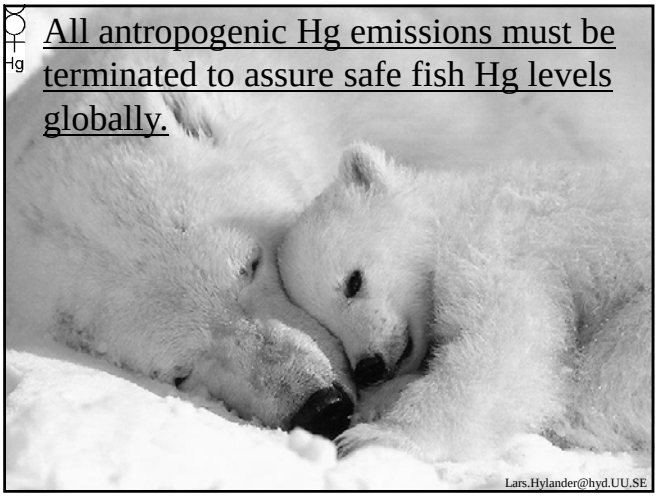
Mothers must know that foetus & kids are most vulnerable to Hg.



Lars.Hylander@hyd.UU.SE

☿ Hg

All antropogenic Hg emissions must be terminated to assure safe fish Hg levels globally.



Lars.Hylander@hyd.UU.SE

☿ Hg

Less Hg use with a transparent Hg trade, allowing many to sniffing into it!

Lars.Hylander@hyd.UU.SE

☿ Hg

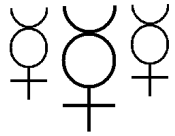
The end of ”vivid silver”

"developments prompted one British mercury dealer in early 1999 to dub Hg a ‘*dying metal*,’ adding that most sales were to companies in developing nations with fewer environmental restrictions”.

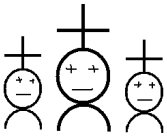
R.F. Manas, AMM News Services

Lars.Hylander@hyd.UU.SE

Dead indeed



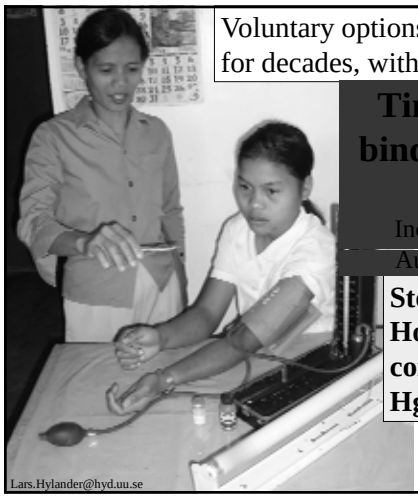
Still causing deaths
in developing countries



Lars.Hylander@hyd.UU.SE

Let's not destroy such an important food source as sea fish!

Lars.Hylander@hyd.UU.SE



Voluntary options have been in effect for decades, without desired effect.

Time to head for binding agreements globally!

Including US, Canada, Australia, and **Japan**!

Stop recycling Hg! How can you contribute to reduce Hg emissions?

Thanks for your attention!
ARIGATOU

Lars.Hylander@hyd.uu.se

Mercury Monitoring in Air and Wet Depositions in Japan

Koji Marumoto

Natural Sciences Section, Department of International Affairs and Environmental Sciences, National Institute for Minamata Disease

The atmospheric concentrations of gaseous and particulate Hg and wet deposition fluxes of Hg at Tokyo metropolitan area and at Matsue City located in a region facing the Sea of Japan were measured. To obtain useful information on the sources and mechanisms of wet deposition processes of atmospheric Hg, the 8 metals (Al, Cd, Fe, Mn, Ni, Pb, V, Zn) and 8 major ions and Pb isotope ratios which are indicators of anthropogenic and natural sources including long range transportation from the Asian continent were also observed. In Tokyo metropolitan area, averaged concentrations of gaseous and particulate Hg were 2.7 ± 1.3 and 0.098 ± 0.051 ng m^{-3}, respectively. From the result of principal component analysis using the data of the metal concentrations in the airborne particulate matters, it is indicated that atmospheric particulate Hg (Hg-P) is related to the particles emitted from municipal solid waste (MSW) incinerators. On the other hand, averaged gaseous Hg concentration, 2.2 ± 0.8 ng m^{-3}, was slightly lower at Matsue City than in Tokyo. The average concentration of Hg-P at Matsue was also one-seventh lower compared to that in Tokyo. This is probably because there is a significant difference in the amount of incinerated MSW between at Matsue and in Tokyo metropolitan area. The Hg-P concentration and wet deposition flux at Matsue were higher in winter and spring than in summer. Especially during spring, their increase was accompanied with the Kosa phenomenon, which frequently occurred during this season. During winter and the Kosa periods, the Pb/Zn concentration ratio and Pb isotope ratios in air and wet depositions at Matsue were close to those in the Asian continent. In addition, the Hg-P concentrations during these periods were significantly correlated with the concentrations of Pb and nss-SO_4^{2-} ($P<0.001$), which are known to be primarily transported from the Asian Continent. These indicate that the large part of Hg-P in air and wet depositions during winter and Kosa periods is emitted in the Asian Continent and long-range transported from this area.

There was significant correlation between monthly wet deposition fluxes of Hg and the monthly precipitation amounts during summer and fall at Matsue ($P<0.001$) and all season in Tokyo ($P<0.001$). The similar relationships between the annual wet depositions and the annual precipitation amounts were also observed at the other sites in Japan. These are probably because Hg wet deposition is dominated by the precipitation scavenging of gaseous Hg (reactive gaseous Hg, RGM) in Japan except for in a region facing the Sea of Japan during winter. The RGM could be originated from the oxidation of elemental Hg (Hg^0) by O_3 and other oxidants in air.

NIMD Forum 2008

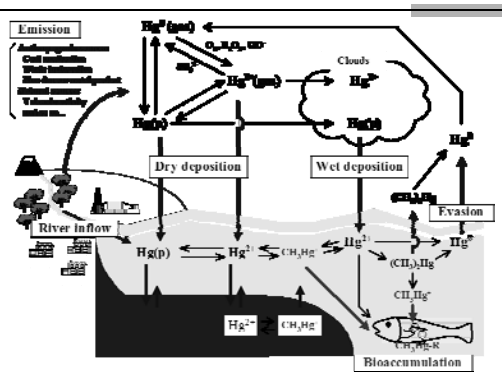
Mercury Monitoring in air and wet depositions in Japan

Marumoto K.

Department of International affairs and Environmental Sciences,
Natural Science Section (NIMD)

NIMD Forum 2008

Background 1
- Mercury cycling in natural environments -



NIMD Forum 2008

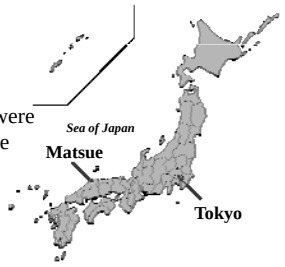
Background 2
- Monitoring of atmospheric mercury in Japan -

- In Japan, atmospheric Hg has been listed as one of air pollutants that should be a priority for regulations since the air pollution control law was amended in 1996.
- In addition, the guideline value on atmospheric Hg has been installed at 40 ng m^{-3} since 2003.
- Monitoring of only atmospheric Hg(0) has been continued at about 300 sites by the Ministry of the Environment since 1996. The average concentration of gaseous elemental mercury observed in Japan was almost 2 ng m^{-3}.
- However, there is no observation for atmospheric Hg(Ⅱ) and Hg(p), wet and dry deposition fluxes of mercury.

NIMD Forum 2008

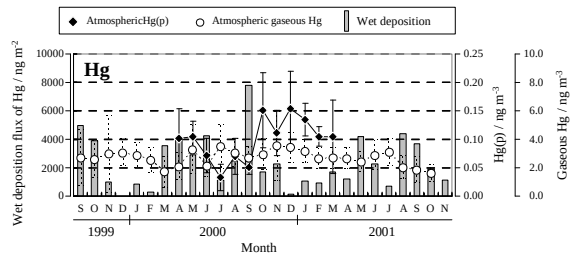
Monitoring of atmospheric mercury in Tokyo and Matsue

- To investigate about behaviors of atmospheric mercury and their emission sources including the long-range transport from the Asian Continent, the concentrations of atmospheric Hg(0) and Hg(p) and wet deposition fluxes of mercury were measured at Tokyo and Matsue from 1999 to 2001.



NIMD Forum 2008

Seasonal variations of atmospheric Hg and Hg wet deposition flux in Tokyo



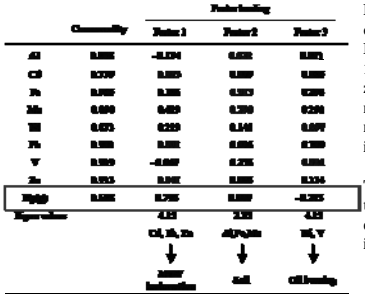
Average concentrations: Hg(0) 2.7±1.3ng m^{-3}, Hg(p) 0.098±0.051ng m^{-3}

Annual wet deposition fluxes of mercury: 31μg m^{-2} in 2000 and 21μg m^{-2} in 2001

NIMD Forum 2008

Atmospheric Hg emission sources in Tokyo metropolitan area

- Principal component analysis based on metal data

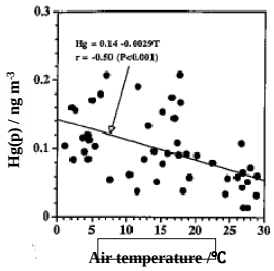


From the result of principal component analysis (PCA), Hg(p) was extracted to Factor 1, which cadmium, lead and zinc had high loadings. These metals were emitted from municipal solid waste (MSW) incineration in Tokyo.

Therefore, it is suggested that the large part of Hg(p) is also emitted from MSW incineration.

NIMD Forum 2008

Relationship between Hg(p) concentrations in air and air temperature

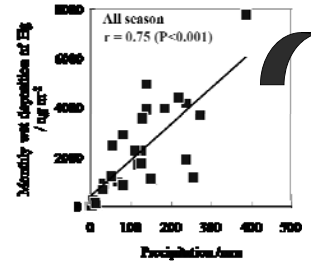


From thermodynamic analysis, Hg(p) concentrations can be changed by the physical adsorption equilibrium of Hg(0) onto MSW incineration particles depending on air temperature.

Data from Sakata and Marumoto (2002)

NIMD Forum 2008

Relationship between wet deposition fluxes of Hg and precipitation in Tokyo

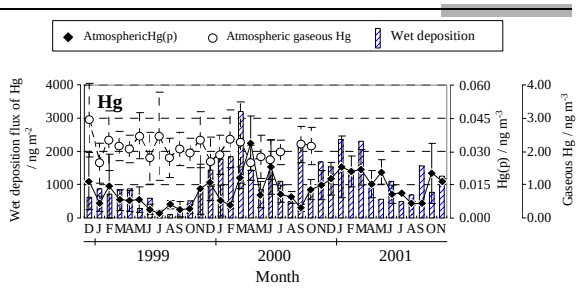


This correlation suggests that atmospheric mercury are constantly taken into rain drop. That is one of the specific characteristics on gaseous components in air, such as sulfur dioxide or nitrogen oxide.

Because gaseous elemental mercury is difficult to dissolve into water, the wet deposition fluxes of mercury in Tokyo are dominated by scavenging of atmospheric gaseous divalent mercury in all seasons.

NIMD Forum 2008

Seasonal variations of atmospheric Hg and Hg wet deposition flux at Matsue

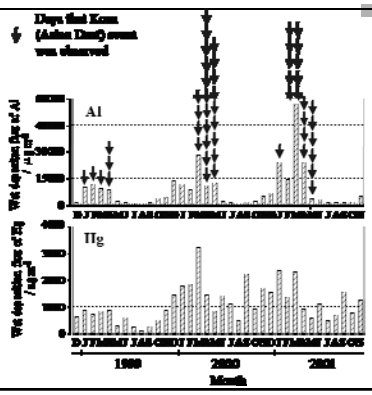


Average concentrations: Hg(0) 2.2±0.8ng m^{-3}, Hg(p) 0.013±0.010ng m^{-3}

3 years averaged annual wet deposition fluxes of mercury: 13μg m^{-2}

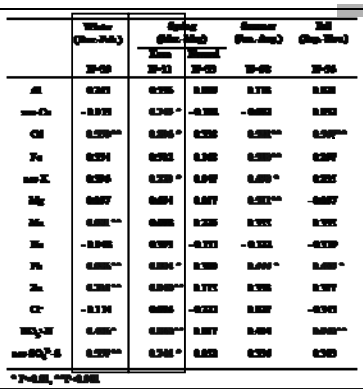
NIMD Forum 2008

Seasonal variations of Al and Hg wet deposition flux at Matsue



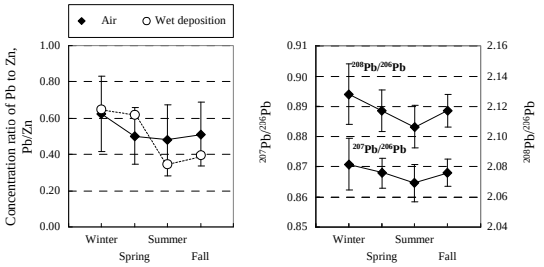
NIMD Forum 2008

Correlation between Hg-P and other chemical components in air in each season at Matsue



NIMD Forum 2008

Seasonal variations of Pb/Zn and Pb isotope ratios in air and wet depositions at Matsue

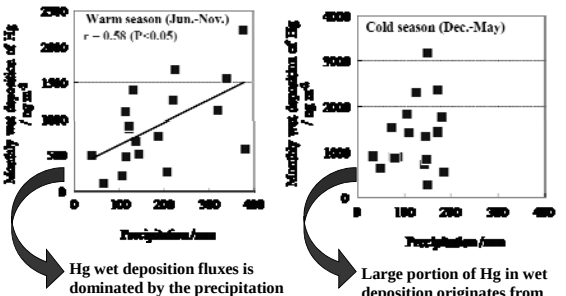


Northern China and Korea
: Pb/Zn = 0.5 -1.0
$^{207}Pb/^{206}Pb$ = 0.87 - 0.88
$^{208}Pb/^{206}Pb$ = 2.12 – 2.16

Tokyo
: Pb/Zn = 0.30±0.07
$^{207}Pb/^{206}Pb$ = 0.863±0.003
$^{208}Pb/^{206}Pb$ = 2.110±0.008

NIMD Forum 2008

Relationships between wet deposition fluxes of Hg and precipitation at Matsue

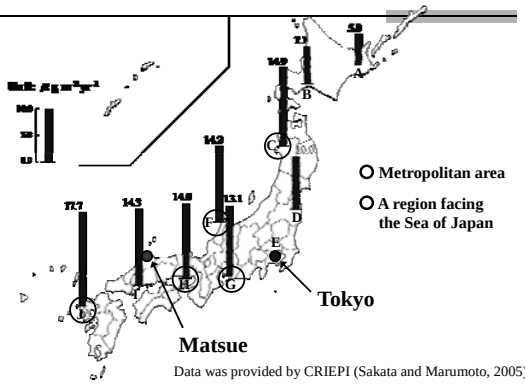


Hg wet deposition fluxes is dominated by the precipitation scavenging of gaseous divalent Hg.

Large portion of Hg in wet deposition originates from atmospheric Hg(p)

NIMD Forum 2008

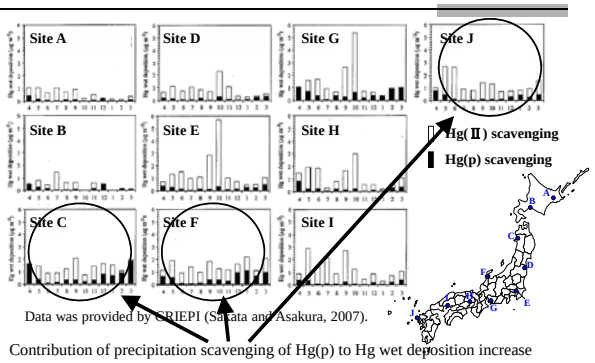
Wet deposition fluxes of Hg in Japan



Data was provided by CRIEPI (Sakata and Marumoto, 2005).

NIMD Forum 2008

Contribution of atmospheric Hg(p) to wet deposition flux of Hg in Japan



Data was provided by CRIEPI (Sakata and Asakura, 2007).

Contribution of precipitation scavenging of Hg(p) to Hg wet deposition increase in winter and spring at these sites which is located in a region facing the Sea of Japan.

NIMD Forum 2008

Conclusion 1

- In Tokyo metropolitan area, the concentrations of atmospheric Hg(p) were higher in winter than in summer, in contrast, wet deposition fluxes of Hg were increased during summer and typhoon season which have a great deal of precipitation.
- At Matsue, the concentrations of atmospheric Hg(p) and wet deposition fluxes of Hg were higher during winter and spring than during summer. In spring, their increase was accompanied with the Kosa phenomenon, which frequently occurred in this season. In addition , the increase of Hg(p) concentrations during winter and Kosa periods were caused by the inclusion of the particles emitted from the Asian Continent and long-range transported.

NIMD Forum 2008

Conclusion 2

- According to the analysis of the precipitation scavenging ratios of Hg and other metals, the large portion of Hg in wet deposition originated from atmospheric Hg(p) in winter at Matsue and other sites which is located facing the Sea of Japan.
- Atmospheric gaseous divalent mercury greatly contributes to the wet deposition flux of mercury at almost sites in Japan.
- The research regarding gaseous divalent mercury in air is needed in future.

NIMD Forum 2008

Future research

- We are preparing the monitoring project on three types of atmospheric mercury and wet deposition fluxes of mercury around Minamata Bay area. We are also going to measure methylmercury in air and wet depositions.

NIMD Forum 2008

Acknowledgement

- This presentation was done based on the data obtained by the Central Research Institute of Electric Power Industry (CRIEPI). The research of Hg wet deposition at 9 sites in Japan except for Matsue and Tokyo was supported by the Ministry of Economy, Trade and Industry. We wish to thank Dr. Sakata, who is the professor of Institute for Environmental Sciences, University of Shizuoka, for providing the data and valuable advices.

Life-cycle Flow Management of Mercury

Misuzu Asari, Shin-ichi Sakai

Kyoto University, Environment Preservation Center, Kyoto 606-8501, Japan

Life-flow management of mercury-containing products from their manufacture to their disposal is essential for the mercury emission control. In Japan, the present status of mercury flow originating from these products was estimated to be about 10–20 tonnes annually, about 5 tonnes of which was attributable to fluorescent lamps, the major mercury-containing product in Japan. The recent rapid increase in digital home electronics with liquid crystal displays (e.g., televisions, personal computers, mobile phones, and digital cameras) has led to a marked increase in the production of backlights, which are also fluorescent and contain mercury. Most of the annual flow was disposed of as waste, with only 0.6 tonnes Hg recovered.

Further, we analyzed the life-cycle inventory of mercury for some types of fluorescent lamps and incandescent bulbs, with various patterns of power stations or management options at the end of the lamps' life. The results suggest that when the amount of mercury released during power generation from coal-fired power stations is taken into account, mercury-containing fluorescent lamps, especially high energy performance products, could reduce the total amount of mercury emissions to the atmosphere compared to incandescent bulbs which themselves are mercury free. We also report the sensitivities of the energy efficiency of lamps, the recovery of mercury from various products at the end of their life, and the improvement of gas cleaning at power plants. It is important to share information and policies regarding fluorescent lamp recycling and related technologies with other countries, especially those in other countries, where fluorescent lamps are becoming more popular because of their high energy efficiency and long life. Also, it is important to develop mercury free and energy efficient lamps including LEDs (light emitting diodes).

Mercury is a household hazardous priority chemical, and we need to limit its use and establish a closed-loop system. There are currently no regulations to achieve this, and the management of most HHWs is left to local governments. Therefore, products are disposed of in landfills or incinerated, except for some that are voluntarily collected and recycled. In order to recycle all of the waste fluorescent lamps, we must have a complete recycling system that has a high rate of public participation in collection. We also must have a closed-loop system of mercury recovery and reuse in which all stakeholders participate.

Life-cycle Flow Management of Mercury

Misuzu ASARI, Shin-ichi SAKAI
Kyoto University Environment Preservation Center

Background

- To prevent and control global mercury pollution, it is necessary to keep an emission inventory and assess the flow of mercury in each country of the world.
- Although coal combustion is thought to be the major source of mercury emissions in Asia, the technology to reduce the burden from coal combustion has been improved in Japan. **Management of mercury contained in products will be the next important step in its control.**
- Mercury is used in a number of household products, such as fluorescent lamps and thermometers. Despite the efforts of industry to reduce the amounts of mercury used, replacement with alternatives has not yet been entirely achieved for many products.
- In terms of hazardous household waste (HHW), recycling systems operating on a commercial scale have been developed for only a limited variety of products, such as televisions, air conditioners, refrigerators, and washing machines. As a result, **most mercury-containing products, including fluorescent lamps, are thought to be disposed of in landfills or incinerated.**

Objectives

Objects of this report are to:

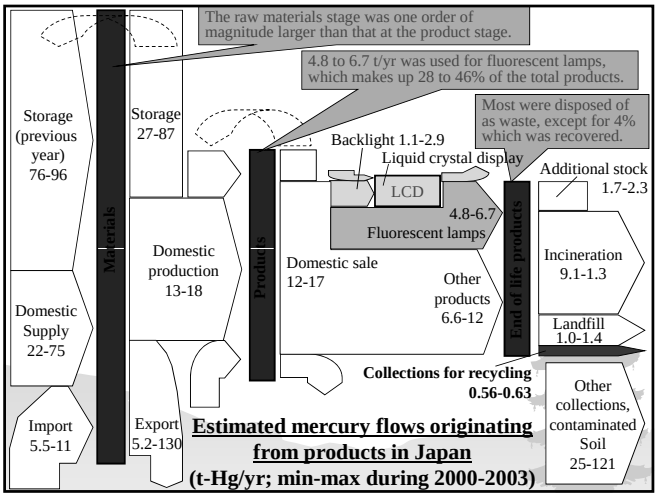
- Summarize the flow of mercury from the manufacture of mercury-containing products to their disposal in Japan,
- Analyzed the life-cycle behavior of mercury for some types of fluorescent lamps and bulbs, with various patterns of power stations or management options at the end of the lamps' life.

How to manage mercury related to products ?

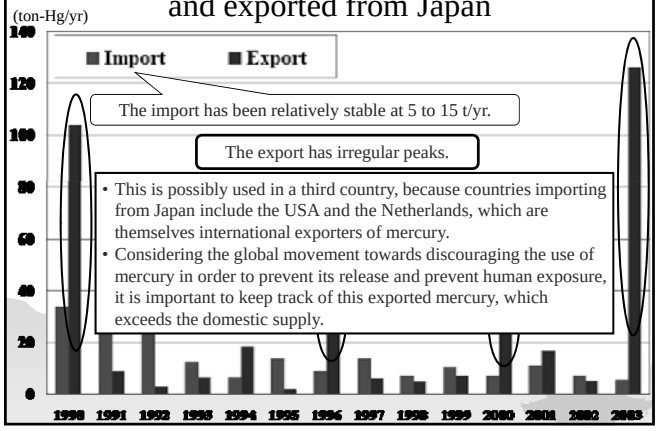
Mercury Flow Originating from Products in Japan

Substance flow analysis for mercury-containing products

- Target: Mercury originating from products in Japanese society (In this analysis, emissions from production processes, impurities in raw materials such as fossil fuels, natural sources, and stocks at landfill or other sites are not included.)
- Method: Estimating annual mercury flow during 2000-2003 from statistical date, hearing surveys or wide questionnaires for each life-cycle stage in Japan
- More about this analysis, see: Asari, M., Fukui, K., Sakai, S., Takatuki, H., Substance flow of mercury and fluorescent lamp recycling, Waste Management Research, 16 (4), 223–235 (2005) [in Japanese]



Materials: Amounts of mercury imported into and exported from Japan

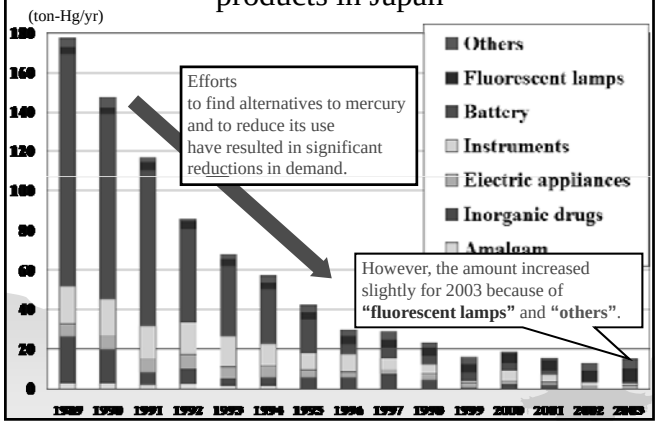


Products: Historical usage

Type of Hg	Chemical formula	Usage
Elemental Hg	Hg	Dry-cell batteries, fluorescent lamps, thermometers, instruments and electric appliances
		Amalgam (for dentisty and alloys)
		Catalysts for production of synthetic chemicals and sodium hydroxide
Inorganic Hg	HgS	Paints, coloring agent for Japanese lacquer "Urushi (Japan)" and vermilion inkpads
	$HgCl_2$	Catalyst for production of chlorinated vinyl, dry-cell batteries and medical reagents (disinfectants, pesticides and preservatives)
	HgO	Reagent, mercury oxide cells and preservatives
	$HgSO_4$	Reagent
	HgCl	Electrode
Organic Hg	$C_2H_5HgSC_6H_4COONa$	Thimerosal (disinfectants)
	$C_6H_8HgO_2$	Agricultural chemical (disinfectants)

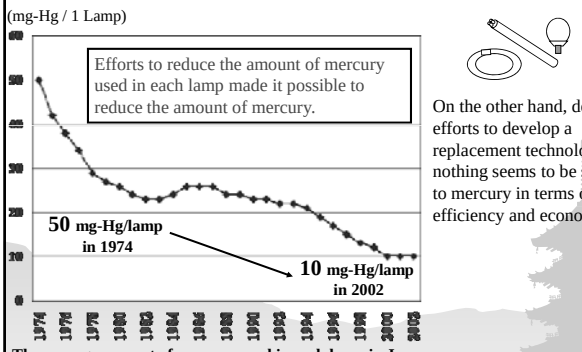
Some uses (such as in sodium hydroxide production, pesticides, and dry-cell batteries, and as a catalyst for acetaldehyde production) have now been discontinued in Japan. However, mercury is still used in various usages in many countries.

Products: Domestic demand of mercury for products in Japan



Products: *Fluorescent lamps*

Fluorescent lamps include a small amount of mercury as an essential substance; however, they are energy-efficient and widely used for domestic lighting.

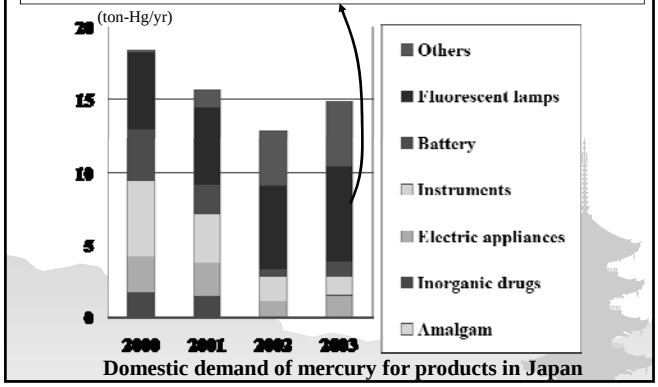


On the other hand, despite efforts to develop a replacement technology, nothing seems to be superior to mercury in terms of efficiency and economy.

The average amount of mercury used in each lamp in Japan

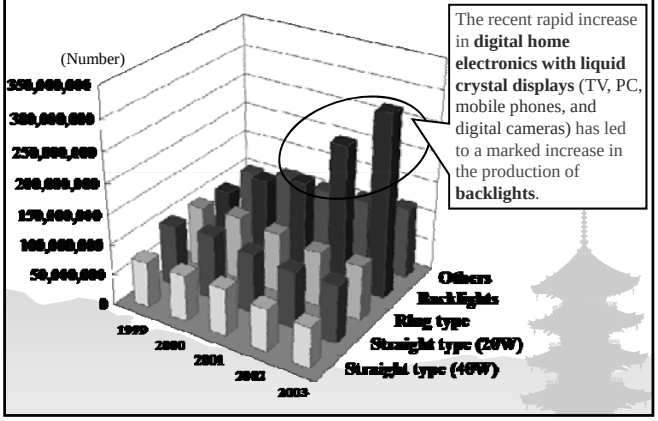
Products: *Fluorescent lamps*

More mercury was used for fluorescent lamps than for any other type of product in 2003, accounting for approximately **40% of the total use of mercury**.



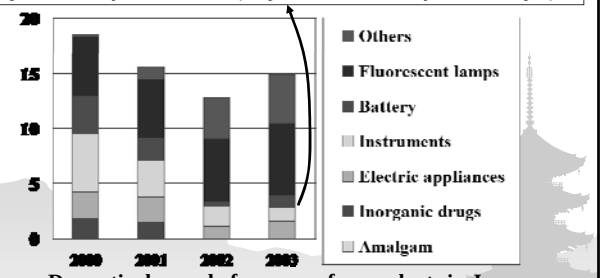
Domestic demand of mercury for products in Japan

Domestic sales of fluorescent lamps



Products: *Batteries*

- Battery production (major mercury-containing battery is silver oxide cell) has remained stable in recent years.
- However, we must focus on international movements such as:
  - Butteries included in imported and exported appliances
  - Amounts of mercury in imported batteries
  - Exported mercury oxide batteries (the production has already ceased in Japan).



Domestic demand of mercury for products in Japan

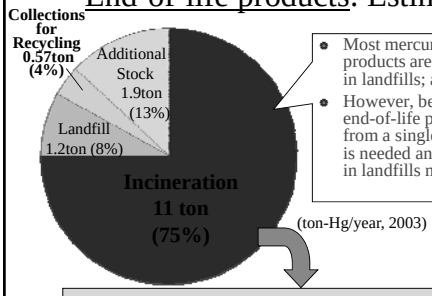
End-of-life products: Calculations

- Assumptions: Domestic sales = [**E**: End-of-life products (domestic)]
  = [**R**: Collections for recycling] + [**S**: Additional stocks] + [**D**: Disposal]
- Calculations: Available data for **[R]** and **[S]** are introduced, and the remained **[D]** are calculated.

Products (BL: Backlight)	Collections for recycling **[R]**	Additional stocks **[S]**	Disposal **[D]** =**[E-R-S]**	
			Incineration	Landfill
Fluorescent lamps excepting BL	Reported values	4.5% of **[E-R]** (from questionnaires)	90% of **[D]****	10% of **[D]****
BL in TV, PC and monitors	-	100%*(Assume not to be disposed yet)	-	-
BL in others	-	-	90% of **[D]**	10% of **[D]**
Amalgam	-	100%*	-	-
Reagents	-	-	90% of **[D]**	10% of **[D]**
Electric appliances	-	-	90% of **[D]**	10% of **[D]**
Thermometers	-	45% of **[E]** (from questionnaires)	90% of **[D]**	10% of **[D]**
Instruments	-	-	90% of **[D]**	10% of **[D]**
Button batteries	Reported values	19% of **[E-R]** (from questionnaires)	90% of **[D]**	10% of **[D]**

**Averaged ratio for the whole wastes in Japan

End-of-life products: Estimated Flow



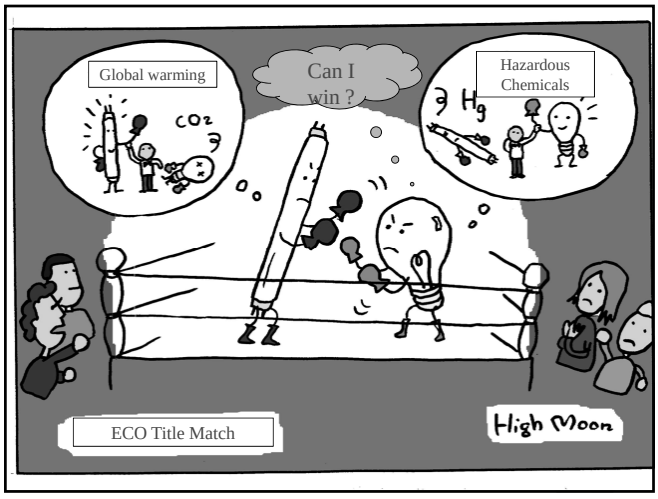
(ton-Hg/year, 2003)

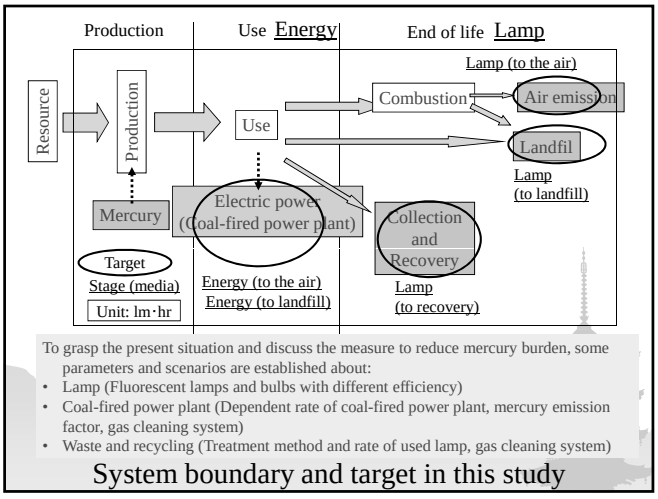
- Most mercury-containing waste products are incinerated or disposed of in landfills; a mere 4% are recycled.
- However, because the calculation for end-of-life products was based on data from a single city (Kyoto city), caution is needed and the amount disposed of in landfills might actually be higher.

2 flue-gas treatment scenarios +
2 ranges for the distributions of emissions from incinerators

0.75 to 7.6 t/yr of mercury is emitted into the atmosphere.
However, more information is required because the behavior of mercury during incineration depends largely on the characteristics of each facility and its operating conditions.

Life-Cycle Behavior of Mercury-Containing Fluorescent Lamps





To grasp the present situation and discuss the measure to reduce mercury burden, some parameters and scenarios are established about:

- Lamp (Fluorescent lamps and bulbs with different efficiency)
- Coal-fired power plant (Dependent rate of coal-fired power plant, mercury emission factor, gas cleaning system)
- Waste and recycling (Treatment method and rate of used lamp, gas cleaning system)

System boundary and target in this study

Scenarios

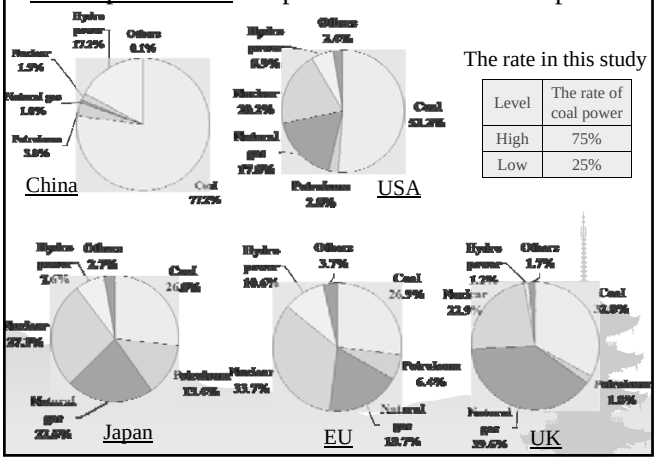
Wattage (W)	Lamp	Coal-fired power	Recycling rare	Incineration
[1] Incandescent lamp/ High burden	Incandescent lamp	High burden	0 %	High burden
[2] Fluorescent lamp/ High burden	Fluorescent lamp C	High burden	0 %	High burden
[3] Fluorescent lamp/ Middle burden	Fluorescent lamp C	Low burden	0 %	High burden
[4] Present condition scenario in Japan	Fluorescent lamp B	Low burden	20 %	High burden
[5] Complete recycling scenario	Fluorescent lamp A	Low burden	100 %	-

Prime parameters: Lamp

Lamp's type			Wattage (W)	Lumen (lm)	Span (hours)	lm/W	Amount of mercury used in lamp (mg/lamp)
40 W	Fluorescent lamp-A	A-40	32	3,520	12,000	110	5
	Fluorescent lamp-B	B-40	37	3,100	12,000	84	10
	Fluorescent lamp-C	C-40	40	2,200	7,000	55	30
	Incandescent lamp	I-40	40	450	1,000	11	0

- Incandescent lamp☼: Lamp itself is mercury free, but its efficiency (lm/W) is low.
- Fluorescent lamp: Lamp itself contains mercury, but its efficiency (lm/W) is high.

Prime parameters: Dependence on coal-fired power



The rate in this study

Level	The rate of coal power
High	75%
Low	25%

Prime parameters: Emission factor from coal-fired power station

Area	Mercury in coal (mg/kg)	Emission factor (μg/MJ)
North America	0.18 (0.01～3.3)	7
Western Europe	0.29 (0.1～2.0)	11.2
Eastern Europe	0.3 (0.15～1.8)	12
Africa	0.18 (0.08～7.0)	7
Oceania	0.2 (0.02～1.3)	7.7
Middle & south America	No report	7
Asia	No report	12
Japan	0.0454 (n=181)	1.2

Gas cleaning is not taken into account.

Gas cleaning is taken into account.

In this study

Mercury emission factor (Amount of mercury in coal)		Efficiency of gas cleaning		Formation of mercury	
Burden	Emission factor (Hg-μg/MJ)	Burden	Removal rate (%)	Hg^0 (%)	Hg^{2+} (%)
High	12	High	0	20	80
Low	7	Low	80	84	16

排ガス水銀化学形態
Sung Jun Lee, et. al. : Mercury emission from selected stationary combustion sources in Korea, Science of the Total Environment, Vol. .325, No. 1-3, pp. 155-161(2004)
西谷隆司：一般廃棄物焼却処理施設における飛灰による排ガス中水銀の乾式除去回収に関する研究 (1999)

Prime parameters: End of life products

Management option of end of life products, and rate of collection for recycling

Management scenario	Disposal rate	Recycling rate
Non-cyclic	100 %	0 %
Product cyclic	80 %	20 %
Product and function cyclic	0 %	100 %

Management at disposal (rate of incineration and direct landfill)

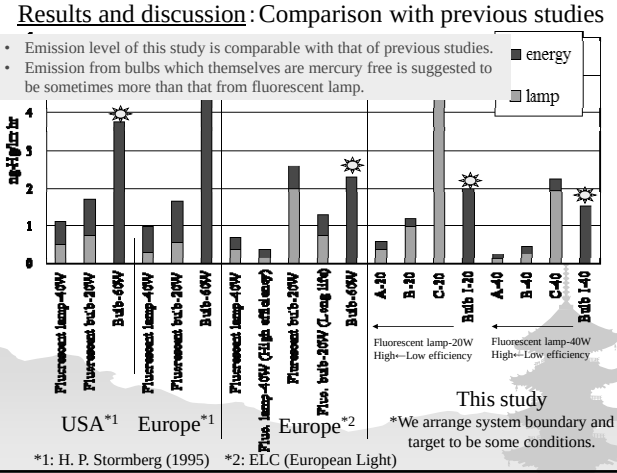
Main management	Incineration	Landfill
Incineration	90 %	10 %
Landfill (direct)	10 %	90 %

Gas cleaning efficiency at incineration

Gas cleaning level at incineration	Mercury removal rate	Hg^0 (%)	Hg^{2+} (%)
High	90 %	96	4
Low	22 %	10	90

Results and discussion: Comparison with previous studies

- Emission level of this study is comparable with that of previous studies.
- Emission from bulbs which themselves are mercury free is suggested to be sometimes more than that from fluorescent lamp.



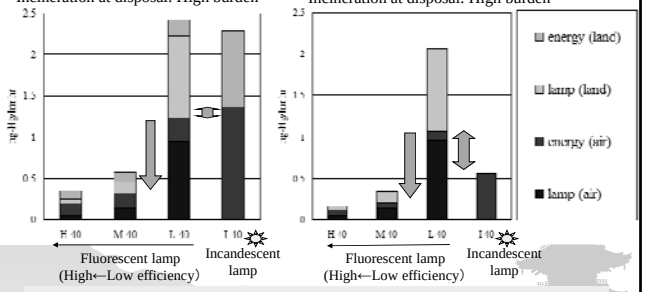
*We arrange system boundary and target to be some conditions.

*1: H. P. Stormberg (1995) *2: ELC (European Light)

Results and discussion: Improvement of lamp's efficiency

<scenario>
Coal-fired power: High burden
Incineration at disposal: High burden

<scenario>
Coal-fired power: Low burden
Incineration at disposal: High burden

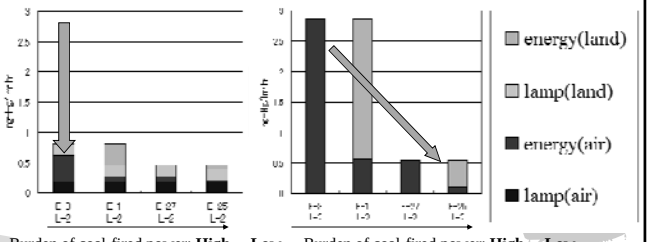


- Improvement of energy efficiency significantly contribute to reduction of mercury emission to the atmosphere, especially in areas where burden of coal-fired power plant is heavy.

Results and discussion: Improvement of gas cleaning at coal-fired power station

<scenario>
Fluorescent lamp: 40 W (Middle efficiency)
Incineration at disposal: High burden

<scenario>
Incandescent lamp: 40 W
Incineration at disposal: High burden



Burden of coal-fired power: **High →Low**

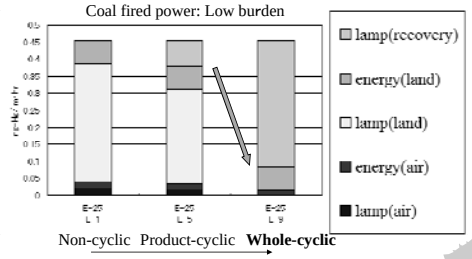
Burden of coal-fired power: **High →Low**

	Dependence on coal	Emission factor	Gas cleaning efficiency
E-3	High	High	Low
E-1	High	High	High
E-27	High	Low	Low
E-25	High	Low	High

- Lifecycle emission from incandescent lamp is high in areas where gas cleaning system is not well.
- Effect of improvement of gas cleaning system is also clear in these areas.

Results and discussion: Establishment of Cyclic system of end of life products

<scenario>
Fluorescent lamp-40W (Middle efficiency)
Coal fired power: Low burden



Non-cyclic Product-cyclic **Whole-cyclic**

Disposal: Non-cyclic→Cyclic

	Disposal option	Main disposal	Gas cleaning efficiency
L-1	非循環	Incineration	High
L-5	製品循環	Incineration	High
L-9	完全循環		

- Life-cycle emission; especially to landfill, is significantly reduced.

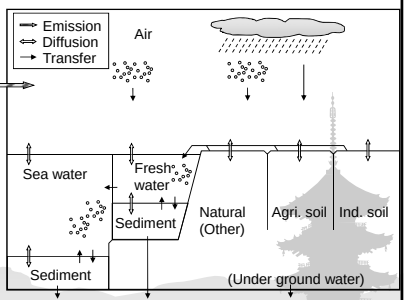
Environmental Model of Mercury Behavior

・Mackay-type Multimedia Fate and Exposure Model-Level III

・Geographical scale
Japan (same land scale and sea area)

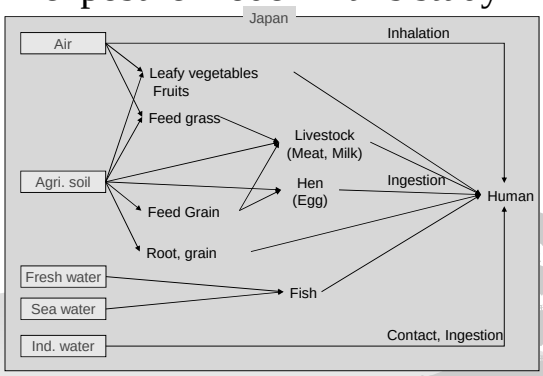
・Environmental Media
Air
Water (Fresh water, Sea water)
Soil (Agri, Industrial, Other)
Sediment (Fresh, Sea water)

・Transformation of mercury compounds
Hg0→Hg2+ (Oxidation)
Hg2+→M-Hg (Methylation)



Outline of environmental behavior

Environmental behavior and human exposure model in this study



Exposure amount = Content in the media (C) × Intake amount (Q)

Results and discussion Intake fraction

iF: intake fraction
Human intake of a pollutant released from a source (individual / mass)

Form at Air emission / Form at Intake		Hg^0	Hg^{2+}	M-Hg	T-Hg	Hg^0	Hg^{2+}	M-Hg	T-Hg
Indivisual	Inhalation	4.8E-13	1.8E-16	1.9E-19	4.8E-13		1.8E-16	1.9E-19	1.8E-16
	Soil	5.1E-17	5.4E-13	3.3E-18	5.4E-13		5.4E-13	3.3E-18	5.4E-13
	Food	-	4.2E-12	4.3E-12	8.6E-12		4.2E-12	4.3E-12	8.6E-12
	Total	4.8E-13	4.8E-12	4.3E-12	9.6E-12		4.8E-12	4.3E-12	9.1E-12
Mass population	Inhalation	6.2E-05	2.2E-08	2.5E-11	6.2E-05		2.2E-08	2.5E-11	2.2E-08
	Soil	6.5E-08	6.9E-05	4.2E-10	6.9E-05		6.9E-05	4.2E-10	6.9E-05
	Food	-	5.4E-04	5.5E-04	1.1E-03		5.4E-04	5.5E-04	1.1E-03
	Total	6.2E-05	6.1E-04	5.5E-04	1.2E-03		6.1E-04	5.5E-04	1.2E-03

・When Hg^0 is emitted into the air, a fraction for intake of total-Hg by mass population (Japanese) is estimated to be 1.2×10^{-3} (0.12%).
・Chemical form of intake is Hg^{2+}(50%) and M-Hg (45%).
・Exposure route is mainly food ingestion (89%).
・The chemical form at the exposure doesn't depend on forms at the emission.
→It's important to reduce total amount of mercury emissions.

Risk of Human Exposure

Estimated amount of exposure per functional unit
= Amount of mercury emission in each scenario at inventory analysis
× Personal iF (intake fraction) (total mercury)

[1] Incandescent lamp/ High burden 2.6×10^{-11} ng-Hg/man/lm·hr
↓ Change of lamps➔50% down
[2] Fluorescent lamp C/ High burden 1.4×10^{-11} ng-Hg/man/lm·hr
↓ Improvement at coal fire power plant➔50% down
[3] Fluorescent lamp C/ Middle burden 9.0×10^{-12} ng-Hg/man/lm·hr
↓ Improvement of FLs and partly recycling ➔90% down
[4] Present in Japan (FL-B) 1.1×10^{-12} ng-Hg/man/lm·hr
↓ Complete recycling ➔90% down
[5] Complete recycling scenario (FL-A) 1.1×10^{-13} ng-Hg/man/lm·hr

More than 50 % of the exposure amount can be reduced by each control method.

Risk of Human Exposure

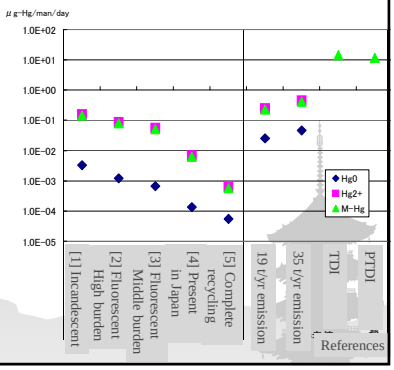
Exposure amount of mercury originated from lighting in Japan

・Total "lm・hr" in Japan was calculated and exposure amounts at each scenario was compared with refferences.

[1] Incandescent lamp/ High burden
T-Hg 0.31 μg-Hg/man/day
M-Hg 0.15 μg-Hg/man/day
➔1% of TDI

[4] Present in Japan (FL-B)
T-Hg 0.013 μg-Hg/man/day
1-3 % of total exposure amount by present emission
➔Other emission sources including incineration of medical waste must be considered to control all products including mercury.

[5] Complete recycling
T-Hg 0.0019 μg-Hg/man/day



Conclusions

- The substance flow of mercury in Japan was summarized for mercury-containing products, and the current management of these products as HHW was described. The amount of mercury flow originating from products was estimated to be around 10–20 t annually. In this flow analysis, it was shown that 5 t was contributed by fluorescent lamps. We found that the use of fluorescent lamps for backlights is increasing, and that most of these fluorescent lamps were disposed of as waste. Only 0.6 t of mercury is recovered annually.
- The life-cycle behavior of mercury suggests that when the amount of mercury released during power generation from coal-fired power stations is taken into account, mercury-containing fluorescent lamps, especially high energy performance products, could reduce the total amount of mercury emissions to the atmosphere compared to bulbs which themselves are mercury free. We also report the sensitivities of the energy efficiency of lamps, the recovery of mercury from various products at the end of their life, and the improvement of gas cleaning at power plants. Exposure amount of mercury was estimated to be 0.15 μg-Hg/man/day (as methyl mercury) at the high burden scenario with incandescent lamp, and it corresponds to 1% of TDI. On the other hand, exposure was controlled to be 0.0019 μg-Hg/man/day (as total mercury) in complete recycling scenario with fluorescent lamp, two orders of magnitude lower.
- These two analyses show that it is important to regulate mercury-containing products such as fluorescent lamps and to establish a closed-loop system of mercury recovery from a life-cycle perspective. Considering global economic activities, it is important to share information and policies regarding HHW management and treatment technologies with other countries.

The Problem of Mercury-containing Wastes in Japan

Risks from Hazardous Household Waste (HHW)

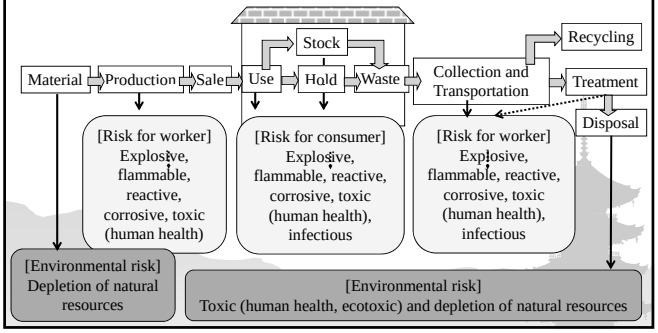
- Household products that need special management because of their hazardous or dangerous properties have been discussed as "waste necessitating special control" or "**Hazardous Household Waste (HHW)**".


Consultation about anxieties

- The concept of hazardous properties for all waste has recently been extended to include not only dangerous properties, such as flammability, but also toxicity originating from **hazardous household chemicals (HHC)**, carcinogenicity, eco-toxicity (toxicity to the natural environment), as well as acute toxicity to humans.

Risks and major hazardous properties existing within the life cycle flow of products

In order to consider and manage the risks from waste products, we must gather information about the **properties of the products** and think about **life cycle management**.



Management of HHW

- Countries of the European Union began work on a life cycle management system with the introduction of the **RoHS Directive** (Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment 2002/95/EC) and the **WEEE Directive** (Directive on waste electrical and electronic equipment 2002/96/EC), which regulate hazardous chemicals during their production and control the environmental burden at the end of their use.
- In Japan, we do not have any regulation corresponding to RoHS; however, **for some end-of-life products, a recycling system has been built** from the viewpoint of waste management and the efficient use of resources in a sound material cycle society.

Current management system for some types of HHW in Japan

	Targeted products	Outline
Targeted by recycling laws	Household appliances ・Televisions ・Air conditioners ・Washing machines ・Refrigerators, freezers	At consumer's expense. Collection and transportation by retailer and recycling by manufacturer with objective recycling rates enforced under The Household Appliances Recycling Law.
	Car parts ・Shredder dust ・Chlorofluorocarbons ・Airbags	At consumer's expense. Collection and transportation by collectors, delivery by wreckers, recycling by manufacturers, and proper treatment and delivery of collected chlorofluorocarbons enforced under the Automobile Recycling Law.
	Personal computers	Voluntary collection by manufacturers and importers. Recycling with objective recycling rate enforced under the Law for the Promotion of Efficient Use of Natural Resources as targeted recycling products.
	Small storage batteries	
Not targeted	Mobile phones	Voluntary collection and recycling done by the Mobile Recycle Network of telecommunication companies and manufacturers.

Current management system for some types of HHW in Japan (continued)

	Targeted products	Measures for heavy metals, including voluntary initiatives by industries
Targeted by recycling laws	Household appliances ・Televisions ・Air conditioners ・Washing machines ・Refrigerators, freezers	Some kind of regulation for their use is implemented by each manufacturer. Use of Pb, Hg, Cr (+6), and Cd is limited, banned with certain regulated exceptions, or totally banned.
	Car parts ・Shredder dust ・Chlorofluorocarbons ・Airbags	Use of Hg, Cr (+6) and Cd is fundamentally banned. In 2005, use of Pb is limited to approximately 1/3 of the level in 1996.
	Personal computers	Regulation for use is similar to that of the 4 household appliances. Au and Co are recovered from used products.
	Small storage batteries	Ni and Co are recovered from used products.
Not targeted	Mobile phones	Au, Pg, Ni, and Co are recovered from used products.

Management of HHW: Current management system for HHW in Japan

- The main purpose of the laws that govern recycling seems to be **volume reduction** and **the recovery and proper treatment of resources**, but these laws also include the **concept of managing hazardous chemicals**.
- However, **only some types of HHW are targeted**, and the management of most HHW is up to each local government. Further, some products are subject to a mandatory recovery rate, and it is **difficult to assess the whole system** without information on the recycling rate or the collection rate of these and other chemicals.

Management system for mercury contained in waste

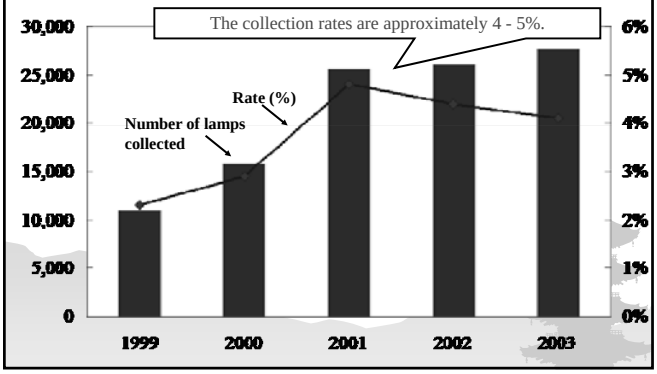
- **Mercury-containing industrial waste needs special management (landfill)**, because this is "specially controlled industrial waste".
- On the other hand, for **mercury-containing HHW**, there are currently **no such regulations**, and the management of most HHW is up to each local government.
- Therefore, products are disposed of in landfills or incinerated, except for some that are voluntarily collected and recycled.

Management of mercury-containing HHW by local governments

City / Products	Fluorescent lamps	Thermometers	Dry-cell batteries	Button batteries
Kyoto 京都	Separate	Combustible	Separate	Ban of release
Sapporo 札幌	Separate	Noncombustible	Separate	Ban of release
Sendai 仙台	Separate	Separate	Separate	Ban of release
Chiba 千葉	Separate	Separate	Separate	Ban of release
Kawasaki 川崎	Combustible	Combustible	Separate	Ban of release
Yokohama 横浜	Combustible	Combustible	Separate	Ban of release
Nagoya 名古屋	Noncombustible	Noncombustible	Noncombustible	Separate
Osaka 大阪	Separate	Separate	Separate	Ban of release
Kobe 神戸	Noncombustible	Noncombustible	Separate	Ban of release
Hiroshima 広島	Separate	Separate	Separate	Ban of release
Fukuoka 福岡	Noncombustible	Noncombustible	Noncombustible	Ban of release

Separate: Separate collection, often to prevent accidents during collection and transportation; not necessarily recycled after collection

Estimated collection number and rate (collection / sale) of used fluorescent lamps



Fluorescent lamps in "bulky waste" at the crusher equipment of a local government, Kyoto, Japan (Oct 2004)

They are collected and transported mainly from households, crushed and separated (some metals) here, and incinerated.

Management system for mercury contained in waste: *Backlights (fluorescent lamps)*

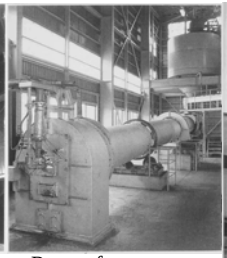
- Backlights in liquid crystal displays for **PCs are collected and recycled separately** within the personal computer recycling system, as regulated by **the Law for the Promotion of Efficient Use of Natural Resources**.
- However, liquid crystal **TVs are not targeted** by the Household Appliances Recycling Law and are instead categorized as "bulky waste".
- Moreover, **other products** containing backlights also **do not currently have any recycling system**.
- Nevertheless, these products must be considered, because a considerable increase in this type of waste is foreseen in the near future.

Recycling method and performance in Itomuka: History

- Nomura Kohsan Co. is the main recycling company for mercury-containing waste in Japan, and the waste is treated at its plant in Itomuka in Hokkaido prefecture.
- In 1939, mercury mining started at Itomuka, but the decline in demand due to pollution problems such as those revealed by the **outbreak of Minamata disease in the 1950s forced the mine to close in 1973**.
- Using the technology and the facilities for mercury mining, the Itomuka plant changed its position to that of **treating mercury-containing waste**.
- In the 1970s, a turning point in the usage of mercury in the sodium hydroxide industry, **the main items treated were sludge, absorbents, dismantled equipment, and polluted soil from sodium plants**.
- In 1975, **recycling of mercury from used dry-cell batteries and fluorescent lamps was started**, and the Itomuka facility is presently the sole recycling (refining) plant for mercury in Japan.

The Itomuka plant has some facilities for different kinds of waste materials with optimum methods

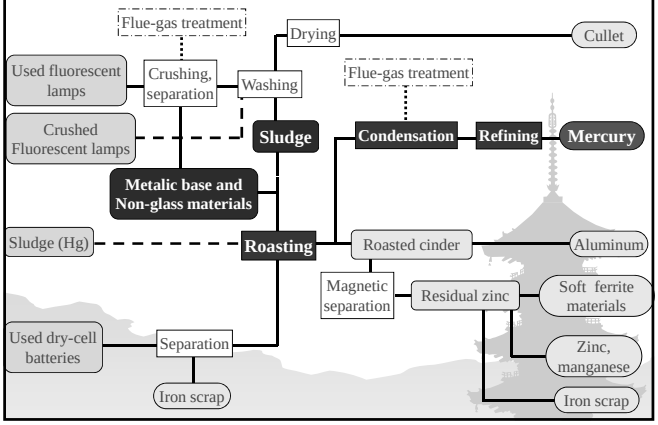
- Large multi-health roasting furnace
- For sludge etc.
- Capacity (Approx.): 100 ton/day



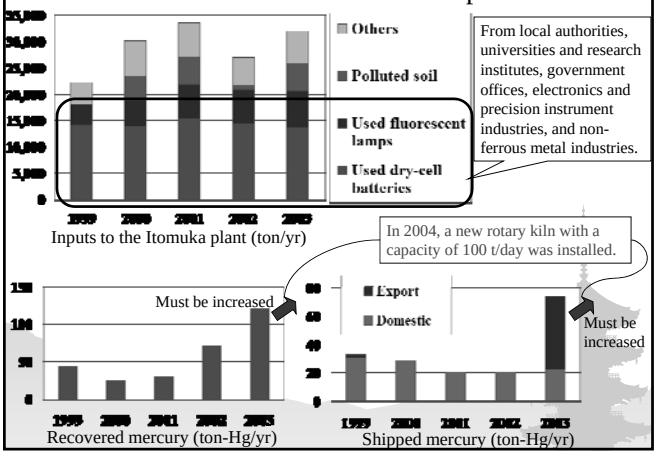
- Rotary furnace
- For dry-cell batteries
- Capacity (Approx.): 20 ton/day

- Condenser tower

Treatment flow chart for used fluorescent lamps and dry-cell batteries at the Itomuka mercury recycling plant



Performance of the Itomuka plant



Issues related to the management of mercury-containing waste

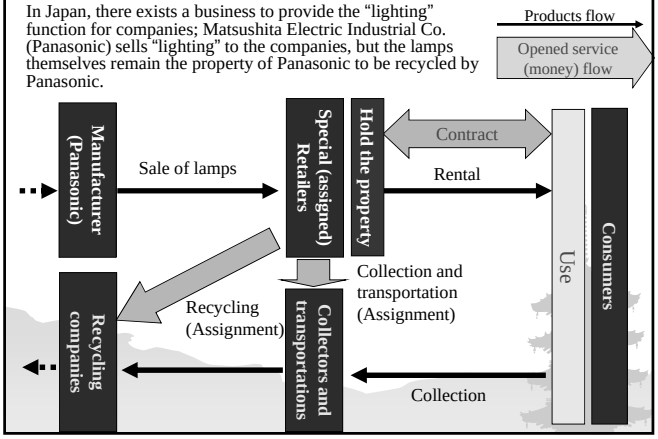
- Only 4% of the total waste mercury originating from products is recycled; most is disposed of in landfills or emitted to the environment. In addition, because the recycled mercury will possibly be exported, **emission to the environment is likely to increase**.
- From now on, systems for managing HHW should be based on the notion of **HHC (hazardous household chemicals)**. The use and management of materials over the **entire life cycle** must be assessed in the context of the **regional and global pollution problem**. For HHW, the collection rate alone is not sufficient; establishment of recovery and detoxification standards and their compliance rates for each HHC are also needed.
- **Mercury is a priority HHC** that must be tackled by regulators, and fluorescent lamps, thermometers, and batteries are the target products. Considering global mercury pollution, **the first task is to avoid its use** as much as possible. For products for which alternatives are not available, **we must limit their use, and establish a closed-loop system**.

Fluorescent lamps case

- In establishing a **closed-loop system**, it is important to control risks during recycling. Of course, **recycling methods** that place a low burden on the environment and human health are required. Moreover, we need to develop **technologies and systems to bring about multiple uses of mercury within the closed system**, so that the recovered mercury will not be a potential source of emission. In addition to the technical problems, **the active participation of citizens** will be an important factor.
- In particular, to ensure a high rate of public participation in the collection of used fluorescent lamps, **some kind of regulation, incentives, or creation of new business models** must be considered.
- To start with, we need to grasp the performance of some models and clearly present a framework on which to build the essential technologies and systems.
- The demand for fluorescent lamps is increasing with new usages such as **backlights**, but except for those installed in PCs, there is no established recycling route for these materials. Appropriate responses to such new uses are required.

"Lighting" assuring service

In Japan, there exists a business to provide the "lighting" function for companies; Matsushita Electric Industrial Co. (Panasonic) sells "lighting" to the companies, but the lamps themselves remain the property of Panasonic to be recycled by Panasonic.



We are still with Hg.

It is important to share information and policies regarding fluorescent lamp recycling and related technologies with other countries, especially those in other countries, where fluorescent lamps are becoming more popular because of their high energy efficiency and long life.

Also, it is important to develop mercury free and energy efficient lamps including LEDs (light emitting diodes).

Thank you for your kind attention!

Progress of Mercury Analysis and the Significance of Monitoring and Quality Control

Milena Horvat, Ogrinc, Vesna Fajon, Darija Gibičar, Jože Kotnik, David Kocman, Suzana Žižek, Radojko Jačimovič

Department of Environmental Sciences, Jožef Stefan Institute, Jamova cesta 30, Ljubljana, Slovenia
**E-mail: milena.horvat@ijs.si, , Tel: +386 1 5885450*

Mercury can exist in a large number of different physical and chemical forms with a wide range of properties. Conversion between these different forms provides the basis for mercury's complex distribution pattern in environmental and biological samples. The paper will demonstrate problems related to recent experiences in mercury speciation in marine waters, biota and sediments. The most important chemical forms in the marine environment are: elemental mercury (Hg°), divalent inorganic mercury (Hg^{2+}), methylmercury (CH_3Hg^+), and dimethylmercury ((CH_3)2Hg). Due to instability of some of these species in environmental samples such as sediments and waters, one of the main source of errors can be related to inappropriate sampling and sample processing. Moreover, during further analytical steps main sources of errors may be related insufficient extraction, low and irreproducible recoveries, insufficient peak resolution in chromatography and transformation of mercury species that may lead to artefacts. In the case of soluble samples such as fish, mussels, etc. speciation analysis has so far achieved most success. However, with solids, techniques to remove or solubilize MeHg are difficult to validate by spiking or tracer approaches, as it is difficult to prove that complete extraction/separation has been achieved. Recently new standard methods have been proposed at national and international levels, which will improve the comparability of data worldwide.

It is important to mention that the quality of mercury analysis and speciation significantly improved in recent years, which contributed to the quality of results in various studies. However, there are still a number of analytical challenges that need to be addressed in the future. The complex environmental behaviour of mercury in the environment is still not well understood and analytical chemists should work closely in interdisciplinary teams to resolve problems associated with proper sampling and sample processing. This, in particular, refers to studies where “dynamic” measurements, such as field fluxes at boundary layers and interfaces (e.g. water/air, sediments/water, soil/air) need to be quantified. On-line and in-line measurement techniques should also be further developed using conventional as well as biosensor techniques. Further challenges also include development of techniques by which mercury binding in biomolecules and interactions of Hg with other elements (i.e. selenium) can be better understood. New developments in separation techniques and detection systems (such as for example MALDI-TOF-MS) will hopefully contribute to new results in the future.

Certified reference materials (CRMs) are available for mercury analysis and speciation in biological samples and sediments and can be used for validation purpose, especially if the matrix and concentration range of certified values match well with samples analysed in a particular study. Due to the absence of CRM/RMs for mercury speciation in marine waters it is important to demonstrate the comparability of the results by other means, including the use of different analytical approaches, i.e., various extraction/separation schemes and detection methods and interlaboratory comparisons. Examples from various interlaboratory comparisons have been performed recently on-board ship (water samples) and laboratory analysis (sediments, biota and water samples). In general, good agreement of the results was obtained in most matrices. Disagreements were observed for difficult samples such as water and fresh sediments, which was due to instability of mercury in these samples rather than differences in analytical procedures used in laboratories.

Progress in mercury analysis and the significance of monitoring and quality control

Milena Horvat
Department of Environmental Sciences
Jožef Stefan Institute, Slovenia
milena.horvat@ijs.si

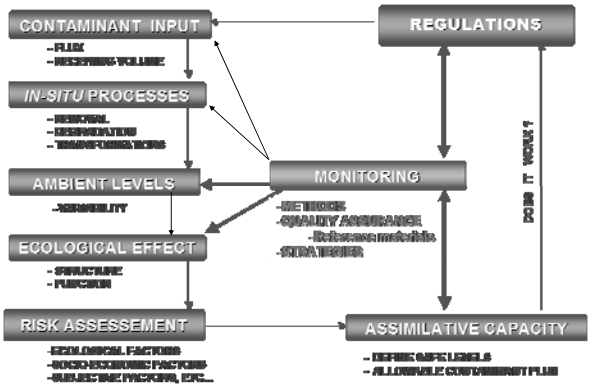
Minamata, NIMD Forum, March 27, 2008

Institute Jožef Stefan

CONTENTS

- *What and why to measure?*
  - *in health, environment, industry, ...*
- *How do we quarantee the results produced are fit-for-purpose?*
  - *Case studies (marine environment, contaminated sites, industry, ...)*
- *Conclusions and recommendations*

Institute Jožef Stefan



Institute Jožef Stefan

BASIC REQUIREMENTS

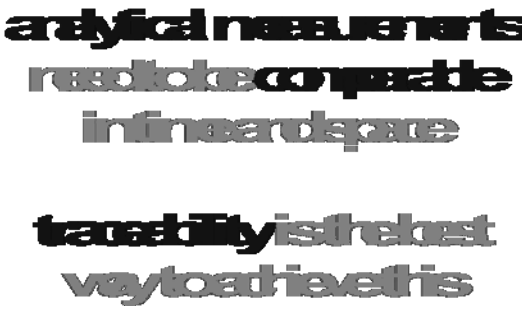
- Antecedents: background information, sampling sites, target contaminants, sources, etc..
- A viable network of committed laboratories: personnel, instrumentation,...
- Methodologies with suitable precision and accuracy
- Quality assurance programme (inter-laboratory studies, quality control, training, equipment maintenance, etc..)
- Good planning and sufficient funds

Institute Jožef Stefan

CHEMICAL METROLOGY

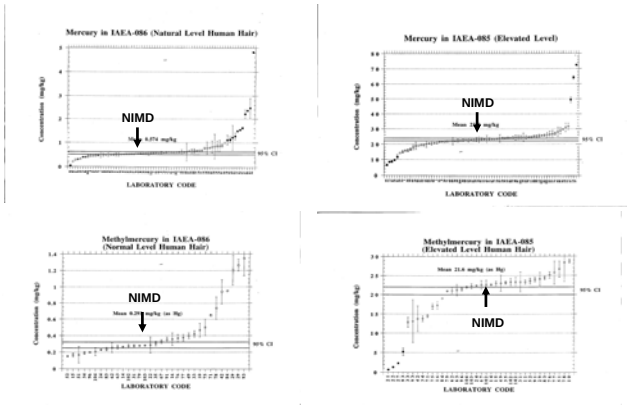
Sampling +	Processing	+ Measurement =	Result
Representative Appropriate Contamination Stability Handling	Dissolution Extraction Dilution	Comparison to SI units or conventional scale	± uncertainty

Institute Jožef Stefan

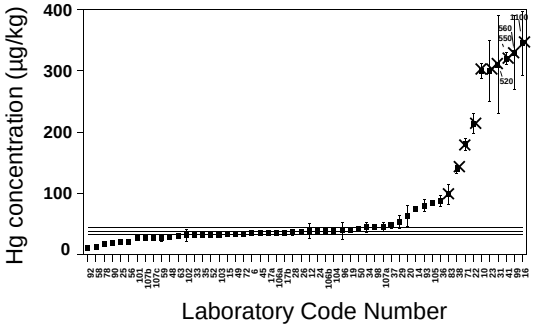


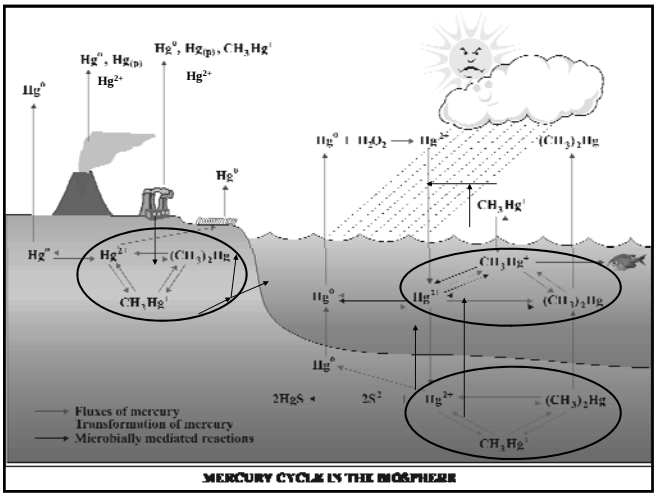
Institute Jožef Stefan

Comparability of data for total Hg and MeHg in human hair



Total mercury
IAEA-140, Sea plant intercomparison exercise





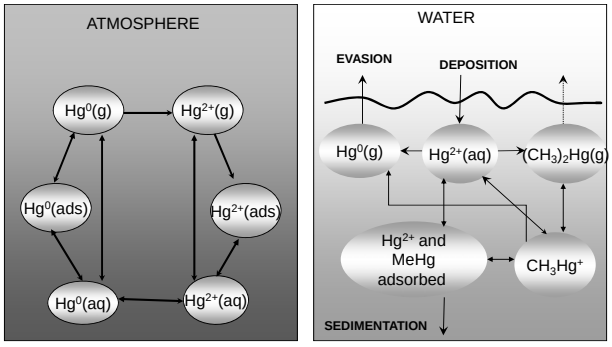
MERCURY CYCLE IN THE BIOSPHERE

Speciation (1)
Why?

- It rules the way Hg is transported from the sources to the local environment of humans and wildlife
- It rules how mercury is bound in the environment and it therefore more or less available to cause adverse effects
- It rules one of the most important mercury exposures and wildlife: the transformation and build up of MeHg in fish and other aquatic and terrestrial foods.

Institute Jožef Stefan

Speciation (2)
A need and a challange for analytical chemists



Institute Jožef Stefan

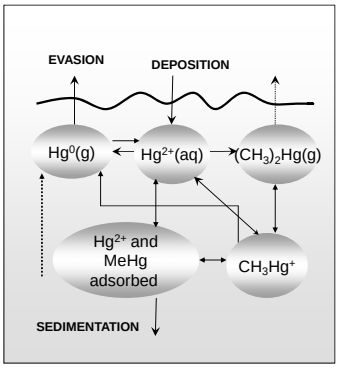
What and why to measure?

- **Total Hg**
- **CH_3Hg^+, Hg^{2+}, reactive Hg, other ionic species?**
- **CH_3HgCH_3, Hg^0 (air, water, gas, oil, flue gases..)**
- **Reactive gaseous Hg, total particulate Hg, Hg bound to particulates, colloidal Hg, reactive Hg in water**
- **Hg in organic molecules (e.g. proteins), Hg bound to humic and fulvic acids, etc.....**
- **Partitioning and fluxes (soil/air, sediment/water, vegetation/air, water/air)**
- **Transformations (methylation, demethylation, reduction, oxidation, etc..)**
- **Kinetics of uptake, distribution and release, retention, biological effects**
- **…..**

Institute Jožef Stefan

WATER -Mercury speciation

- Reactive mercury
- Total mercury
- Dissolved mercury
- Total methylmercury
- Dissolved methylmercury
- Total gaseous mercury (TGM)
- Dimethylmercury (DMM)

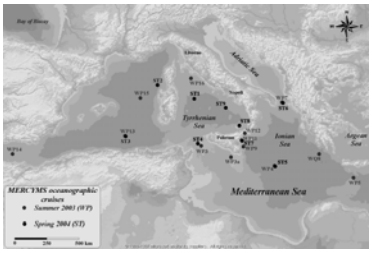


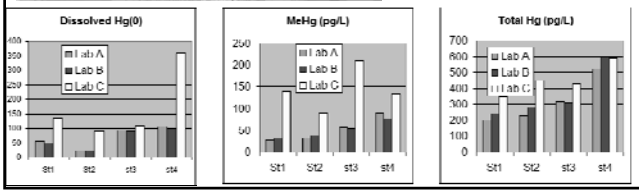
Institute Jožef Stefan

Intercomparison

-On-board (Hg(0))
-In the laboratory (MeHg, THg)

Sampling locations: - summer 2003 (13 locations)
- spring 2004 (9 locations)

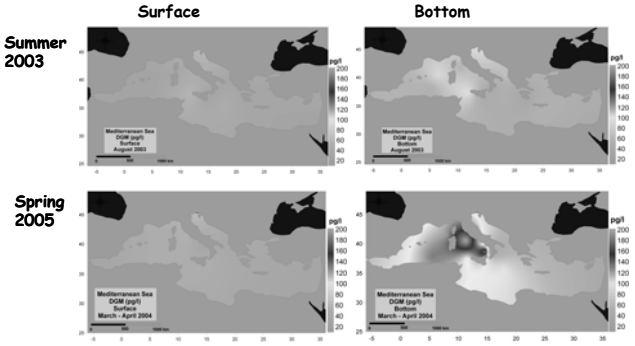




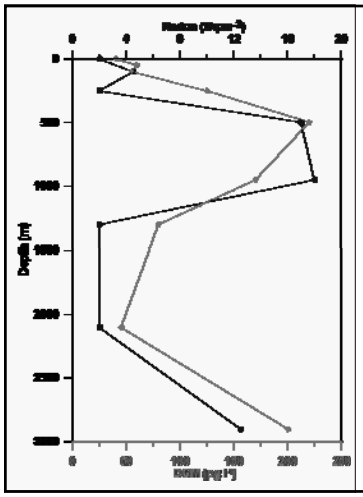
Comparison of the results – surface waters

Study area	T-Hg ng/l	R-Hg ng/l	T-MeHg pg/l	DGM pg/l
Summer 2000	0.29 ± 0.08	0.16 ± 0.06	56 ± 10	30 ± 24.1
Summer 2003	0.20 ± 0.12	0.05 ± 0.06	63 ± 36	34 ± 21
Spring 2004	0.18 ± 0.07	0.06 ± 0.05		65 ± 40
Fall 2004 (Adriatic)	**0.59 ± 0.26**	**0.12 ± 0.10**	**89 ± 49**	**45 ± 40**
Fall 2004 (Mediterranean)	0.38 ± 0.08	0.05 ± 0.02	103 ± 23	35 ± 17
Summer 2005 (Adriatic)	**0.67 ± 0.36**	**0.11 ± 0.10**	**87 ± 34**	**64 ± 35**
Summer 2005 (Mediterr.)	0.35 ± 0.07	0.07 ± 0.05	81 ± 23	36 ± 17
W Mediterranean (Cossa *et al.* 1997)	0.51 ± 0.25	0.08	< 30.1	< LOD – 78.2
N Atlantic (Mason *et al.* 1998)	0.48 ± 0.32	0.16 ± 0.03	209 ± 217	96.3 ± 62.2
Equatorial Pacific (Mason and Fitzgerald 1993)	n.d.	0.09 – 0.37	< LOD – 56.2	8.02 – 65.2
S and Equatorial Pacific (Mason and Sullivan 1999)	0.58 ± 0.24	0.34 - 0.24	n.d.	n.d.

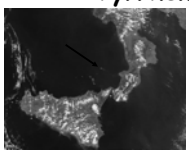
Spatial distribution of DGM



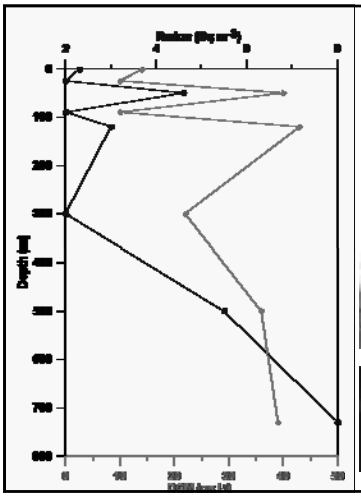
Horvat et al., Atm. Environ. 2003
Kotnik et al., Mar. Chem. 2007



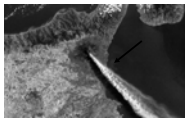
Correlation between Rn and DGM - Tyrrhenian Sea

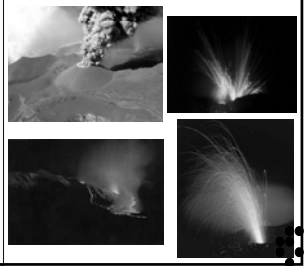


Vaupotic et al., RMZ, 2004
Vaupotič et al. Mar. Chem. submitted

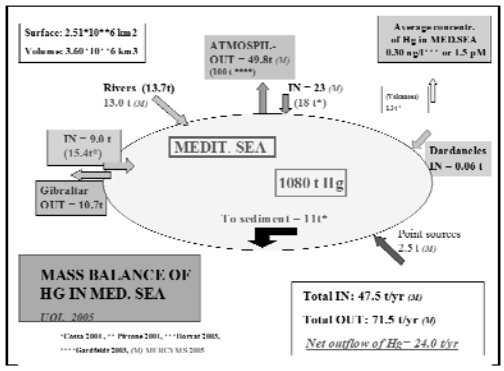


Correlation between Rn and DGM - under Mt. Etna





Hg in the Mediterranean - mass balance

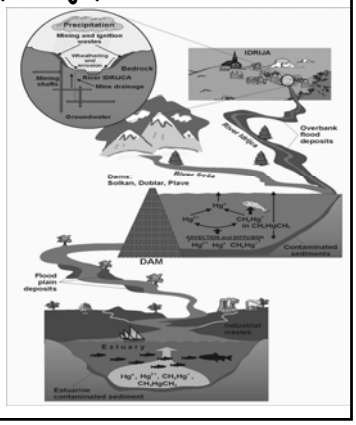


Rajar et al. STOTEN, 2006
Rajar et al., Mar. Chem. 2007, Žagar et al., Mar. Chem. 2007

Rajar et al., 2007

Contaminated sites

Contaminated sites: Mercury mine, Idrija, Slovenia



Horvat et al., 2000

Sediments/soils – what to quantify?

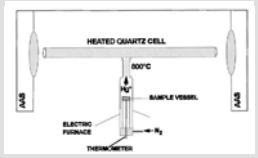
- Total Hg, CH_3Hg^+, Hg^0
- Other chemical forms:
  - Sequential extraction
  - Pyrolysis
- EXAFS
- Transformation potential: methylation, demethylation, reduction?
- Microbiology, ...

Institute Jožef Stefan

Mercury binding forms (1)

Pyrolysis
(Biester et al. 1997)

Study of thermal release behaviour
Hg^0, $HgCl_2$,
Hg bound to humic acids, HgS

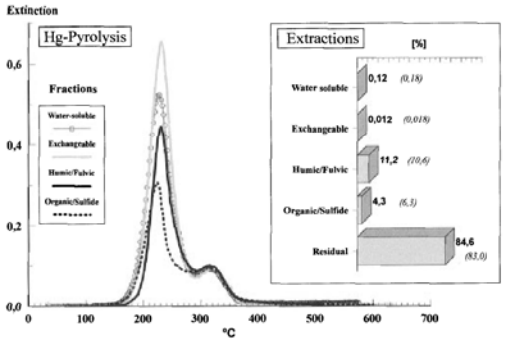


Sequential extraction
(DiGuilioo and Ryan, 1987)

1. **(Thermal desorption – Hg(0)), 60^{0}C**
2. **Water soluble**
3. **Exchangable**
4. **Humic/fulvic**
5. **Organic/sulfide**
6. **Residual**

Institute Jožef Stefan

Mercury binding forms (2)
Soil sample distant from cinnabar deposits



Biester et al., 1997)

Institute Jožef Stefan

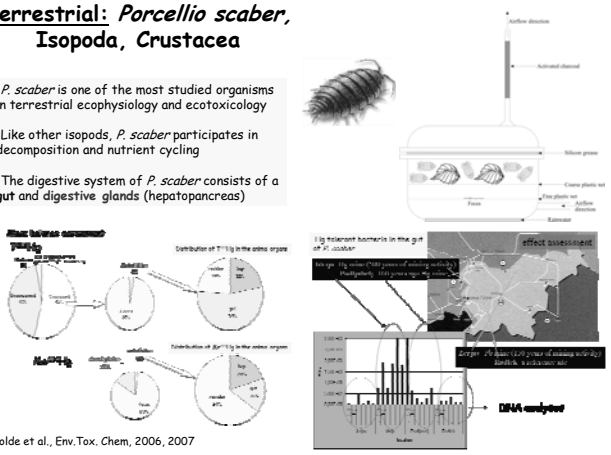
Mercury binding forms – mercury mining area

- Hg binding in soil/sediments in Idrija depends on the:
  - age of the tailings (different roasting techniques)
  - Particle size
- Younger tailings (lower Hg conc.) contain higher concentrations of leachabale Hg – higher potential for transformation/transport

Institute Jožef Stefan

Terrestrial: *Porcellio scaber*, Isopoda, Crustacea

- *P. scaber* is one of the most studied organisms in terrestrial ecophysiology and ecotoxicology
- Like other isopods, *P. scaber* participates in decomposition and nutrient cycling
- The digestive system of *P. scaber* consists of a gut and digestive glands (hepatopancreas)



Nolde et al., Env.Tox. Chem, 2006, 2007

Mercury mine Idrija, Slovenia Inhaled vs. ingested Hg in roe deer

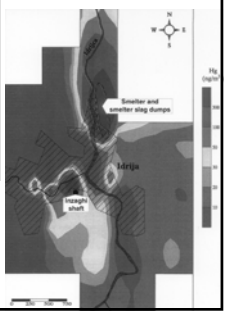
Location	Hg intake into roe deer		
	Inhalation	Ingestion	Inhalation: ingestion
	Hg (µg/kg/day)	Hg (µg/kg/day)	Ratio (%)
Idrija – Zone A	0.10	109	0.09
Zone B	0.30	435	0.07
Near smelter	4.0	2520	0.16
Podljubelj	0.07	36.5	0.19
Controls	0.007	4.2	0.17

Gnamuš and Horvat, EST, 2001

Mercury flux at the soil/air inteface

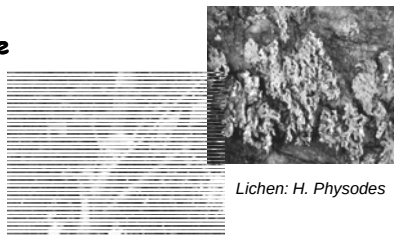
- Zone A: 50 – 300 ng/m^2/h
- Zone B: 4 – 55 ng/m^2/h
- Control: to a max of about 3.8 ng/m^2/h
- Mercury flux is a function of:
  - Lithology,
  - Temperature, UV radiation
  - Hg concentration in soil,
  - Soil moisture(frequency of rain events)
  - Distance from the faults
  - wind

Note: Yearly evaporation from the catchment 500 – 1500 kg (subject to further studies)

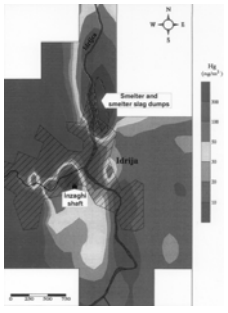


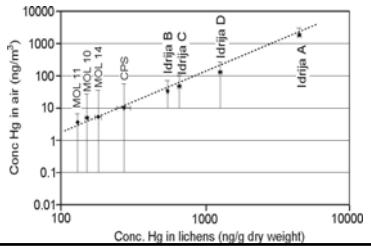
Institute Jožef Stefan

Hg in air – passive and active monitoring using biomonitors

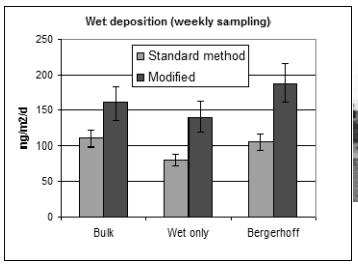


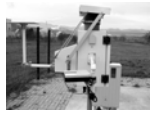
Lichen: H. Physodes



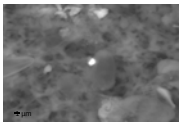


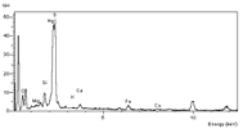
Hg in Deposition – Idrija, 2007





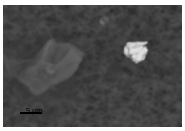
River water samples

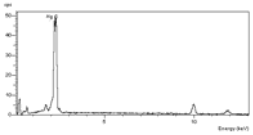




SEM/EDXS microscopy of suspended matter in the Idrijca River,
marked grain represents a qualitative spectrum (belonging graph) of the cinnabar particle,
low content of suspended matter is observed, material of organic origin is dominating (dark colored parts)

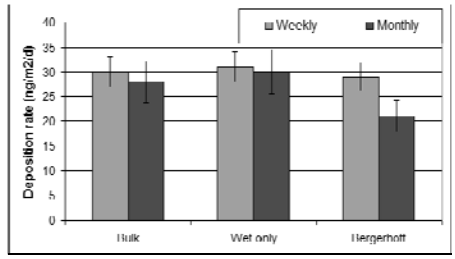
Rain water samples





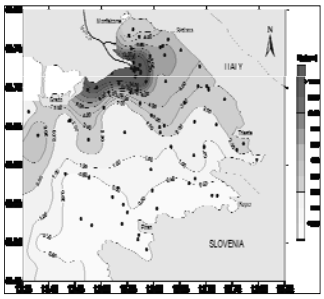
SEM/EDXS microscopy of suspended matter in the rain water from location Idrija, marked grain represents a qualitative spectrum (belonging graph) of the cinnabar particle, low content of particulates is observed, filter fibers represent the uncovered area of the filte

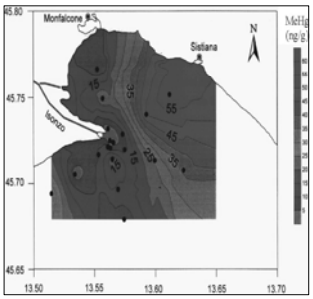
Mercury deposition



Mercury in marine sediments

Total Hg MeHg





SAMPLING:

Critical step in mercury analysis and speciation

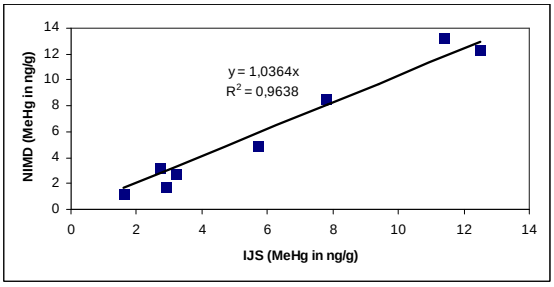
- Contamination
- Losses (evaporation, adsorption)
- Transformations (preserve conditions in the nature)

Institute Jožef Stefan

Analytical methods

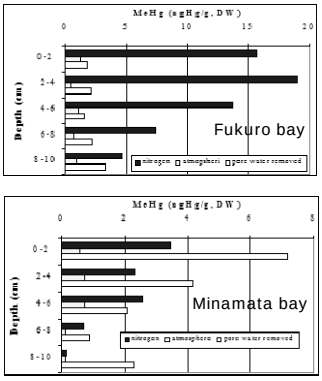
IJS	NIMD
Acid leaching/solvent extraction	Acid leaching/solvent extraction of Hg dithizonates
⇩ Ethylation/purg&trap	⇩ Clean-up
⇩ GC/CV AFS	⇩ GC-ECD

Comparison of the results for MeHg between IJS/NIMD



SAMPLING, Minamata, 2001:

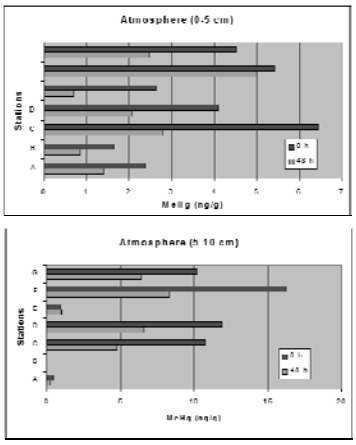
MeHg IN MARINE SEDIMENTS



SAMPLING, Minamata, 2003:

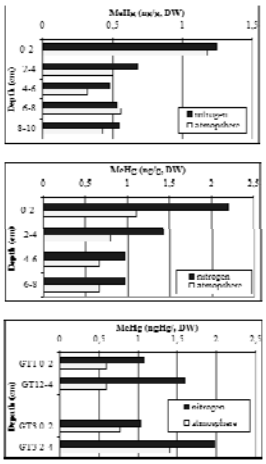
MeHg IN MARINE SEDIMENTS

Analysis of wet samples stored under atmospheric conditions – the effect of time



The Gulf of Trieste
September 2003

Total Hg: <1mg/kg

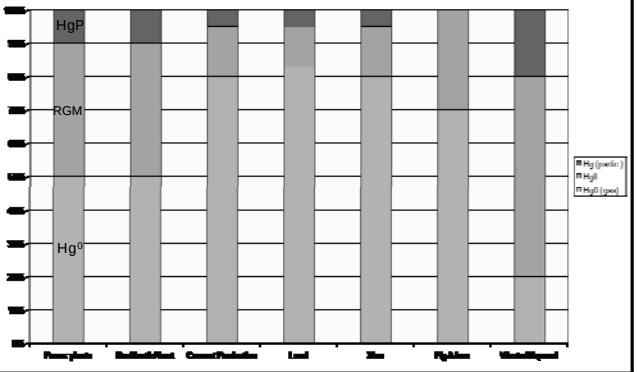


Mercury in industry

Point source emissions - speciation

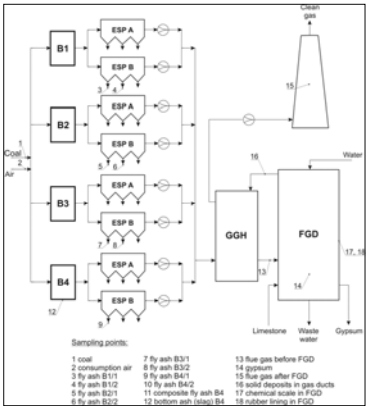
- Combustion processes emit Hg^0, oxidised mercury (RGM) and small fractions of Particulate mercury (HgP)
- RGM and HgP will deposit on local to regional scales whereas Hg^0 may disperse hemispherically/globally
- Measurement methods for speciation exist but are not frequently applied - inventories rely on estimates
- Uncertainties in available data on speciation are large

Speciation of emitted mercury

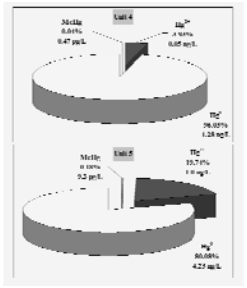


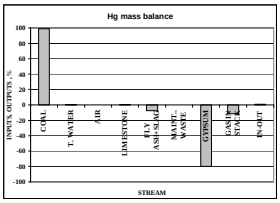
HgP – particulate mercury; RGM – Reactive Hg; Hg^0 – elemental mercury

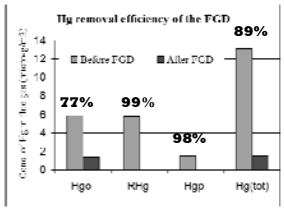
Case study (1/2):
Lignite burning TPP
(775 MW)



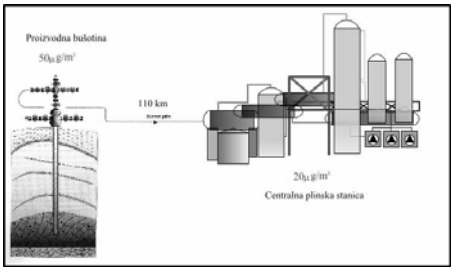
Case study (2/2):
Lignite burning TPP



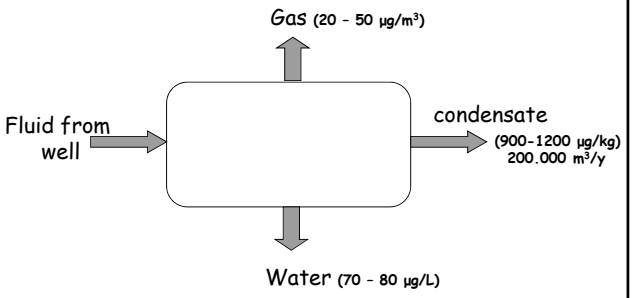


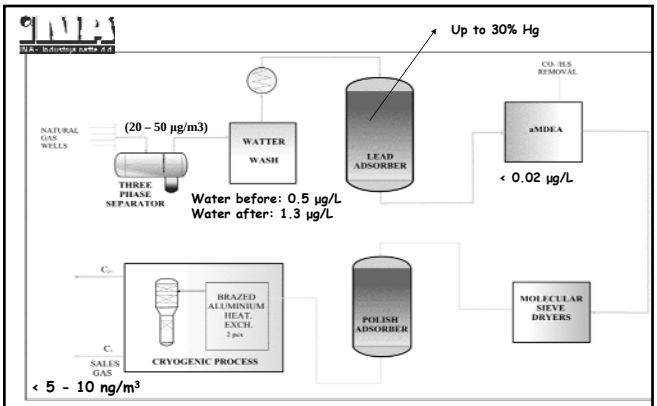


Natural gas treatment plant,
Molve, Croatia



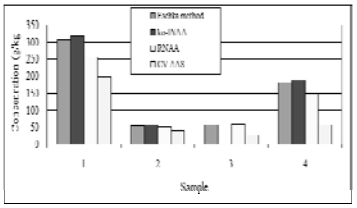
MOLVE



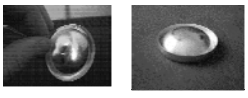


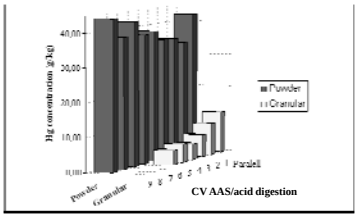
GTP Molve III – block sheme

Determination of total mercury in activated carbon – natural gas facilities



Eschka method - gravimetry





Conclusions

- **Good plannning and method validation is needed before any measurement campaign**
- **SAMPLING and sample treatment is the main source of uncertainty in mercury speciation**
- **The use of CRMs do not guarantee the accuracy**
- **Currently available CRMs are not sufficient to establish comparability of chemical measurements (concentration and matrix match!)**
- **In order to achieve comparability of the results, proper uncertainty budgets and traceably need to be established (complience to basic metrology principles)**
- **BIOMONITORING should further be promoted and standardized**

UNEP Mercury Programme and Activities on the Environmentally Sound Management of Mercury Waste

Desiree Narvaez

UNEP Chemicals Division of Technology, Industry, Economics,
11-13 chemin des Anémones, CH 1219 Chatelaine, Geneva, Switzerland
Tel: +41 22 9178865,Fax: +41 22 7973460 email:dnarvaez@chemicals.unep.ch

Mandate for the activities: This activity started in 2001, when the UNEP Governing Council (GC), through **decision 21/5,** invited UNEP to undertake the Global Mercury Assessment (GMA). The GMA report confirms that mercury is persistent and cycles globally. The GC concluded that there was sufficient evidence of significant global adverse impacts from mercury and its compounds on humans and wildlife to warrant further international action to reduce the risks to human health and environment, with an increasing problem in developing countries. D**ecision 22/4 V** called for national, regional and global actions to be initiated urgently. This was reiterated in **GC decision 23/9 IV** in 2005 which brought the establishment of the UNEP mercury programme in the Chemicals Branch of its Division of Technology, Industry and Economics (DTIE) .

GC 24/3 last February 2007 recognized that current efforts to reduce risks from mercury are not sufficient to address the global challenges posed by mercury and recognized that a range of activities are required to address the challenges posed by mercury.

Partnerships – GC 24/3 calls for the strengthening the UNEP Global Mercury Partnership. Currently, there are 5 partnership areas with business plans at various stages of development: artisanal gold mining, chlor alkali production, products, fate and transport, as well as coal combustion. Expansion areas of the partnership include vinyl chloride monomer production, waste combustion, non-ferrous metals mining and cement production. Discussions on the Global UNEP Mercury Partnership overarching policy framework, goals and operational guidelines will be the focus during the April 1-3 Meeting of Partners in Geneva.

Open Ended Working Group (OEWG) - GC 24/3 decided further, to establish an O**EWG** of Governments and stakeholder representatives to review and assess options for enhanced voluntary measures and new or existing international legal instruments. The first meeting of the OEWG took place in Bangkok last November 2007. As part of intersectional work for OEWG 2, UNEP secretariat has called for various information from Governments, NGOs and stakeholders which cover the response measures outlined in the strategic objectives.

C**urrent Activities of the UNEP Mercury Programme:**

1. **Guidance materials on mercury -**

- "Toolkit for identification and quantification of mercury releases" – results of pilot testing at national level with selected countries is under way
- "Guidance to Estimating Exposure to Identify Populations at Risk" will soon be published
- "Guide for Reducing Major Uses and Releases of Mercury"

2. **Capacity building and technical assistance activities** to support efforts of countries, especially developing countries and countries with economies in transition, to take action on mercury pollution under the mercury small grants programme.

3. **Work with the Basel Convention Secretariat** in the development of technical guidelines for the environmentally sound management of mercury waste.

In order to test the applicability and usefulness of the technical guidelines on the ESM of mercury waste, country projects are being proposed with the following **components**:

1. Review of the national inventory and other data on mercury waste
2. National stakeholders meeting to orient stakeholders on the technical guidelines, develop prioritization criteria, and select sources/sectors for promoting ESM
3. National mercury waste management plan drafting and workshop
4. ESM application in selected sources/sectors through creation of working groups on selected sources/sectors, workshops, and dissemination of the guidelines in specific settings: awareness-raising, information dissemination, and training workshops
5. Assessment of laboratory capacities to do mercury sampling and analysis of environmental and biological samples and initial proposals to address gaps in local capacity
6. Evaluation/stakeholders consultation and final report to include evaluation of the prioritization process and the waste management plan as well as the applicability of the technical guidelines to be reported to the partnership on mercury waste management/combustion and report for international dissemination

UNEP MERCURY PROGRAMME

and Projects on the Environmentally Sound Management of Mercury Waste

NIMD Forum 2008, Minamata, Japan, 26-27 March 2008

Desiree M. Narvaez
UNEP Chemicals
United Nations Environment Program

1

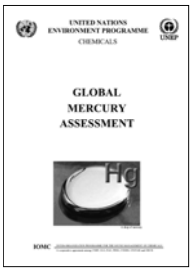
Overview of presentation

- Mercury – a global problem
- UNEP Governing Council mandates
- Demand, trade, and supply
- Partnerships area
- Open ended working group
- Ongoing activities
- Projects on ESM of mercury waste

2

The problem with mercury –

- Mercury is toxic and has negative effects on human health and the environment
- Global assessment was initiated by UNEP Governing Council at its 21st session in Feb 2001
- Responded to concerns that national/regional actions were not sufficient to address mercury pollution



.

3

Global Mercury Assessment Key findings- global cycling

- Hg is persistent and cycles globally – emissions in any continent can contribute to deposition in others

  thus an international issue
- Due to long-range transport, even nations with minimal Hg releases, and other areas remote from industrial activity, may be adversely affected.

Foto.com

Coal-fired power plant

4

Key findings – growing problem in developing countries

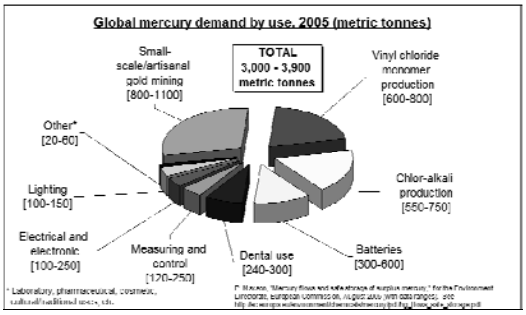
- Hg may be more problematic to less-developed regions (growing energy demand, poor waste treatment facilities, artisanal gold mining activity, etc.)
- Uses being phased out in developed countries may still be ongoing in developing countries

UNIDO

Using liquid Hg to amalgamate gold

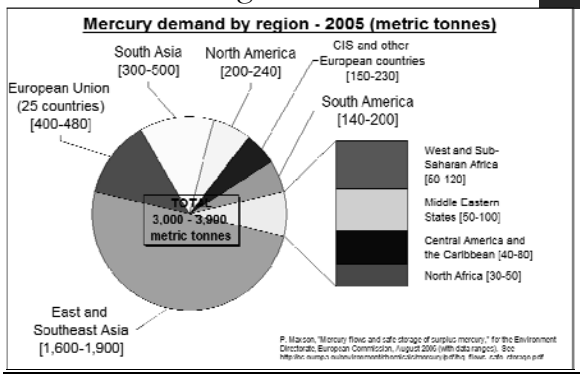
5

Mercury continues to be used…



6

… and there is a global demand.



7

GC Decision 22/4 in 2003
Need for global policy response

The Governing Council

- Endorsed conclusions of the Working Group
- Decided (GC 22/4) national, regional and global actions should be initiated ASAP

UNEP Headquarters Nairobi

- Urged all countries to adopt goals and take actions to identify exposed populations and reduce anthropogenic Hg releases

8

Establishment of a UNEP Mercury Programme

- To support efforts of countries to take action to reduce Hg pollution, the Governing Council requested UNEP to initiate technical assistance and capacity building activities to support the efforts of countries.
- In response, UNEP established a mercury programme within its Chemicals Branch in Geneva, Switzerland.

United Nations, Geneva

9

UNEP Mercury Programme -

Aims to assist countries understand and address Hg problems, through

- Building inventories of uses and releases
- Identifying populations at risk
- Developing communication and outreach to at-risk populations
- Initiating actions to reduce uses and releases of Hg, including promoting Hg-free products, technologies and processes, using environmentally friendly alternatives
- http://www.chem.unep.ch/mercury/

10

GC 23/9 in 2005: Strengthened the UNEP Mercury Programme

- Reiterated the conclusions of the GMA report on the global adverse impacts of Hg on health and environment
- Reiterated its decision that national, regional and global actions should be initiated ASAP

- Urged all countries to adopt goals and take actions to identify exposed populations and reduce anthropogenic Hg releases

11

UNEP Governing Council 24
Decision 24/3 IV

- *Recognizes* that current efforts to reduce risks from mercury are not sufficient to address the global challenges posed by mercury;
- *Concludes*, therefore, that further long-term international action is required to reduce risks to human health and the environment and that, for this reason, the options of enhanced voluntary measures and new or existing international legal instruments will be reviewed and assessed in order to make progress in addressing this issue;

12

Approaches to managing the problem

- Two main ways forwarded identified by Decision GC 24/3
  - strengthen the United Nations Environment Programme mercury programme partnerships
  - establish an ad hoc open-ended working group of Governments, regional economic integration organisations and stakeholder representatives to review and assess options for **enhanced voluntary measures and new or existing international legal instruments**

13

Many definitions/interpretations…

*"…**Partnership** is a cross-sector collaboration in which organisations work together in a transparent, equitable and mutually beneficial way. The partners agree to commit resources, share the risks as well as the benefits to work together towards a sustainable development goal."*

Definition of 'partnership' currently used by The Partnering Initiative, January 2005

14

Mercury partnership activities currently underway

- artisanal/small-scale gold mining;
- coal combustion;
- chlor-alkali sector;
- reduction in products
  - batteries, dental amalgams, measuring and control (lmedical sector), electric and electronic switches, flourescent lamps, cosmetics; and
- air transport and fate research.

15

New partnership areas proposed by Governing Council Decision.

- vinyl chloride monomer production
- non-ferrous metals mining
- cement production
- waste combustion

16

UNEP Governing Council 24 Decision 24/3 IV

- *Urges* Governments to gather information on means to reduce risk that may be caused by the supply of mercury, considering:

(a) Reduced reliance on primary mercury mining in favor of environmentally preferable sources of mercury such as recycled mercury ;

(b) Options and solutions for the long-term storage of mercury and regional activities to improve data on imports and exports of mercury and enforcement of customs controls

17

UNEP Governing Council 24 Decision 24/3 IV: A UNEP report on

- Atmospheric emissions data and trends, including analysis by country, region, and sector
- Current results from regional modeling
- Sector based best practices for reducing mercury emissions including costs
- Analysis of information on risks associated with contaminated sites, mitigation options and costs, its contribution to global mercury releases
- Promote inventories of mercury use and release

18

Legally binding approaches

- Possibilities for a legally binding approach include:
  - Utilisation of relevant elements of existing instruments
  - Drafting new protocols or procedures for inclusion in existing instruments
  - Negotiation of a new agreement which may cover
    - Mercury
    - Mercury and other chemicals of global concern

19

Planned activities until GC 25 (Feb 2009)

- Ongoing work to develop structure and enhance activities of partnership areas
- First meeting of an ad-hoc Open Ended Working Group to review and assess options for enhanced voluntary measures and new or existing international legal instruments, November 12-16, 2007
- Overarching meeting to develop partnership objectives and overall goals, April 1-3,2008

20

Planned activities until GC 25 (Feb 2009)

- Activities to reduce uses and releases of mercury will be ongoing throughout 2007 and 2008
- Second meeting of the OEWG
  - October 2008
  - Will present options and any consensus recommendations to the Governing Council at its twenty-fifth regular session;

21

UNEP Guidance Document - Toolkit for Inventory Development

- Completed in Nov 2005
- Translations in other UN languages
- Pilot testing at national level with selected countries

http://www.chem.unep.ch/mercury/toolkit/default.htm

22

UNEP Toolkit for Inventory Development will provide:

- Summary of release pathways & source types
- Guidance on how to develop an inventory, focused on a stepwise approach:
  - from gathering simple qualitative information to developing a detailed quantitative inventory
- Detailed descriptions of source categories, including example data, input factors, and output distribution factors
  - to be supplemented as experience is gained

23

UNEP Guide on Use and Release of Mercury

- **Power & Heat Production and Refinement and Use of Oil & Gas**
- **Primary (virgin) Metal Production**
- **Production of recycled metals 'secondary production'**
- **Production of other minerals and materials with Hg impurities39**
- **Intentional use of Mercury as an auxiliary or catalyst in industrial processes**
- **Production, use and disposal of consumer products with intentional use of mercury**
- **Other intentional products/process use**
- **Waste Incineration**
- **Waste treatment, disposal, deposition/landfilling**

24

UNEPWHO Guidance document "Identifying Populations at Risk from Mercury Exposure"

- Identify populations at risk due to Hg exposure
- Estimate exposure
- Communicate risks to vulnerable groups

25

Synergies with the Basel Convention

Mandate: Basel COP 9 and GC 24/3

- Component 1: Development of technical guidelines on the environmentally sound management of mercury waste
- Latest draft to presented to Basel COP
- Component 2: Technical assistance and capacity building activities in selected countries

26

Basel Convention

•Central Policy instrument is **Environmentally Sound Management (ESM):**

"taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes"

•ESM includes minimizing the generation of such wastes, reducing transboundary movements, improving treatment and disposal, and ensuring such wastes are handled as close as possible to where they were generated

Project: Management of Mercury Waste and Waste containing Mercury

General Objective:

- To test the applicability and usefulness of the technical guidelines on the ESM of mercury waste and in doing so
- …provide **technical assistance** and **capacity building** activities on the ESM of mercury waste
- Promote global partnership on mercury waste management/waste combustion

28

Specific Objectives:

1. To review and evaluate the results of the **mercury inventory toolkit**
2. To **orient** national, local and other sectoral stakeholders on the draft technical guidelines on the ESM of mercury waste
3. To **prioritize** mercury sources/sectors and **use the guidelines** in specific settings

29

Specific Objectives (Cont.):

4. To build national and local capacities through **training** in the collection and analysis of environmental samples as well as biomonitoring samples from exposed populations
5. To enable national and local Governments to develop **mercury waste management plans and risk reduction measures**
6. To **evaluate the applicability** and usefulness of the technical guidelines on the ESM of mercury waste

30

Expected output:

1. National and sector-specific stakeholders oriented on the technical guidelines
2. Criteria and process for the prioritization of sources and sectors documented
3. National mercury waste management plan and sector-specific action plans completed
4. Technical guidelines disseminated in specific settings

31

Expected output (Cont.):

5. Key personnel trained in collection and analysis of environmental and biomonitoring samples
6. Improved technical guidelines on ESM of mercury waste
7. Results and lessons learned from the country projects disseminated globally
8. Enhanced global partnerships on mercury waste management and waste combustion

32

ANNEX 2: Gantt chart: Timeframe of activities

Activity	2008											
	M	A	M	J	J	A	S	O	N	D	J	F
Project Preparation: Discussion with selected countries; Consultant hiring (local and international)												
Review of the national inventory and other data and orientation of project												
National stakeholders meeting: prioritization of mercury waste sources and sectors												
National mercury waste management plan												
ESM application in selected sources/sectors												
Training and field work on mercury sampling and analysis												
Evaluation/stakeholders consultation												

33

ANNEX 2: Gantt chart: Timeframe of activities (Cont.)

Activity	2009									
	M	A	M	J	J	A	S	O	N	D
Project Preparation: Discussion with selected countries; Consultant hiring (local and international)										
Review of the national inventory and other data and orientation of project										
National stakeholders meeting: prioritization of mercury waste sources and sectors										
National mercury waste management plan										
ESM application in selected sources/sectors										
Training and field work on mercury sampling and analysis										
Evaluation/stakeholders consultation										

34

Further information can be found at:

http://www.chem.unep.ch/mercury/

United Nations Environment Programme
Chemicals
UNEP Mercury Programme

35

Risk Assessment of Industrial Chemicals Aiming at Better Risk Management

Akihiro Toukai

Research Center for Chemical Risk Management
National Institute of Advanced Industrial Science and Technology
16-1 Onogwa Tsukuba, JAPAN

Risk assessment of industrial chemical substance in Japan has intensively tackled for several years not only in the research center for chemical risk management, AIST, but also other national institute such as NIES(National Institute for Environmental Studies) in JAPAN. Especially, during seven years research project on chemical risk assessment and management, we have developed analytical method for risk assessment with the special interest of exposure analysis. In addition to this, we have prepared risk assessment document for about 150 substances as screening assessment and in-depth risk assessment document for about 30 chemicals. Some of them are already open to the public.

In this talk, I will explain following topics with some case studies form our research project. Firstly I will show briefly the whole structure and strategy of this research project. Secondly, I will show you some case studies of risk assessment of priority chemicals in this project. Thirdly, I will explain you about the importance of risk assessment supported by environment and exposure monitoring and modeling.

We have deeply tackled fate and exposure modeling work employing spatially resolved emission amount of chemicals based on Japanese Pollutant Register Transfer Register System. We have developed fate and exposure model for all the environmental medial and opened them to the public. These models enable us to identify the critical path of the chemicals with small amount of preparation work such as estimation specific chemicals emission amount.

Based on our criteria for selecting high priority chemical, we have prepared risk assessment document for priority chemicals. As one of our distinction of preparing risk assessment document, we have intensively involved main interest party such as external experts, industry people and government people. Based on this communication among interest party, our risk assessment document is for practical use to industrial sector and public sector especially in assisting voluntary management by industrial sectors.

We often face the data poor situation in risk assessment. To overcome this problem, we think continuing effort for monitoring and modeling work for risk assessment is indispensable for better tool for risk management.

AIST

080327 NIMD

Risk Assessment of Industrial Chemicals aiming at better Risk Management

Akihiro Tokai, Dr. Eng.
E-mail: a-toukai@aist.go.jp

Research Center for Chemical Risk Management (CRM)
National Institute of Advanced Industrial Science & Technology (AIST), Tsukuba, JAPAN

AIST

Today I have asked to talk about the overview of risk assessment and its importance of environmental monitoring apart from the issue of mercury. In connection to this, I plan to talk about following three things.

1. Overview of our research project of chemical risk assessment at CRM ’01-’06.
2. Two case studies of risk and exposure assessment from our research project.
3. Implications of monitoring, modeling for better risk management.

AIST

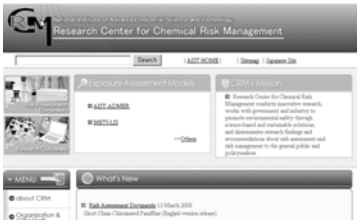
Before I talk about today’ subject, I would like to introduce what we are. The Aims in establishment of CRM/AIST is

- To support government institutions, business, and general public to make rational, scientific decisions, by means of exemplification of results of scientific research.
- To develop methodology required for risk assessment and risk management indispensable in making environmental safety and chemical use compatible.

Continues.

AIST

You can see our research activities in detail through following pages.



In our research center,

We have 7 laboratories.

- **Atmospheric Environment**
- **Hydrosphere Environment**
- **Ecological Risk Analysis**
- **Risk Analysis**
- **Risk Management Strategy**
- **Environmental Exposure Modeling**
- **Health hazard Assessment**

http://unit.aist.go.jp/crm/index_e.html

AIST

Talk outline

1. Overview of our research project of chemical risk assessment at CRM ’01-’06.
2. Two case studies of risk and exposure assessment from our research project.
3. Implications of monitoring, modeling for better risk management.

AIST

Risk assessment research project:
Comprehensive Chemicals Assessment Program
funded by Ministry of Economy, Trade & Industry
through New Energy & Industrial Technology

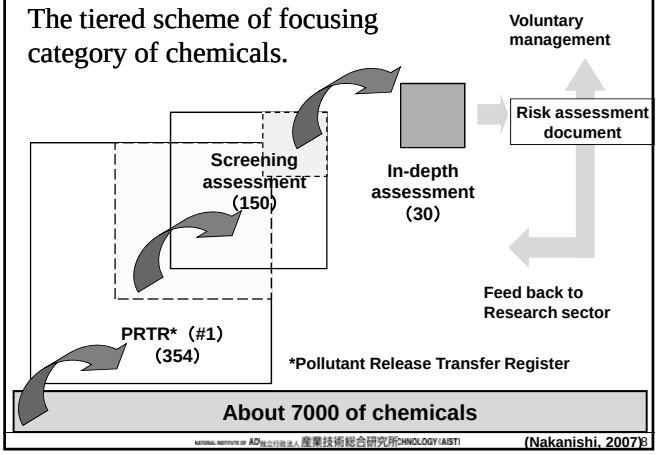
Project Leader: Junko Nakanishi, Director of CRM/AIST
Number of staff: around 50
Project period: 2001- 2006
Purpose: quantify risk of priority chemicals in Japan, and develop tools for risk quantification.

Risk=hazardous property × exposure amount

◆Overview of our research project of chemical risk assessment at CRM ’01-’06

- Tiered Scheme.
- Criteria for selecting priority chemicals.
- Concept of in-depth risk assessment.
- Research output.

The tiered scheme of focusing category of chemicals.



(Nakanishi, 2007)

Criteria for selecting priority chemicals for in-depth risk assessment document

◆Chemicals whose risk has been estimated and concerned from screening risk assessment.

◆Chemicals that cause many discussions by stakeholders.

◆Risk of chemicals has been examining in the international organization.

◆Already regulated chemicals in the past.

◆Chemicals appropriate for method development.

（Nakanishi, Gamo）

Basic concept of preparation of in-depth risk assessment document

◆To assist government and industry decision making timely.

◆Chief distinctions.

- High resolution of spatial exposure pattern. Then, identify high risk population.
- Comprehensive literature review.
- Not only health risk but also ecological risk.

Chemicals in-depth risk assessment required through screening assessment

	Path/usage	Substances estimated as relatively high risk.
Health	**Indoor air quality**	**benzene, xylene, formaldehyde, Chloroform, styrene**
	Food	**acetaldehyde, DEHP,acrylamide, pyridine, acrolein**
Ecological	**detergent**	**Nonylphenol, Alcohol Ethoxylate, Linear Alkylbenzene Sulphonates**
	metals	**Nickel compound, Zinc (soluble), CN, B, Se**

（Tsunemi, NITE）

Risk assessment document open to public

1,3-Butadiene
TBT
Nonylphenol
DEHP
1,4-dioxane
Toluene
Dichloromethane
Chlorinated paraffin
BPA
p-dichlorobenzene
Lead
Copper pyrithione
Acetaldehyde
vinyl chloride

853 304 327 796 660 665 606 508 569 482 538 722 522 636 748 50 50

(# of distribution)

AIST

Talk outline

1. Overview of our research project of chemical risk assessment at CRM '01-'06.
2. Two case studies of risk and exposure assessment from our research project.
3. Implications of monitoring, modeling for better risk management.

AIST

Nonylphenol ethoxylates

is detergent for industrial use. Here, we used next index as quantitative risk.

$$\text{Risk} = \text{Probability}(C_{env} > \text{NOEC})$$

$$\text{Risk} = \text{NOEC}/C_{env}$$

AIST

In quantifying risk, we integrated each element below, next formulae in-depth risk assessment. They are exposed population, consumption amount per person, emission amount per consumption, fate, exposure and dose-response analysis. Then, prioritize each options in terms of cost/benefit.

$$\Delta Risk = Population \cdot \frac{Consumption}{Person} \cdot \frac{Emission}{Consumption} \cdot \frac{C_{env}}{Emission} \cdot \frac{\Delta Dose}{C_{env}} \cdot \frac{\Delta Risk}{\Delta Dose}$$

Population dynamics	Market research	Substance Flow analysis	Fate analysis	Exposure analysis	Dose Response analysis

$$Prioritize_i \frac{Cost_i}{\Delta Risk_i}$$

AIST

Key questions

- How serious is the ecological risk incurred through the usage of nonylphenol ethoxylates and nonylphenol (NPE/NE) in Japan?
- How can we structure the risk management system and what kind of alternatives are comparatively effective from the viewpoint of efficiency?

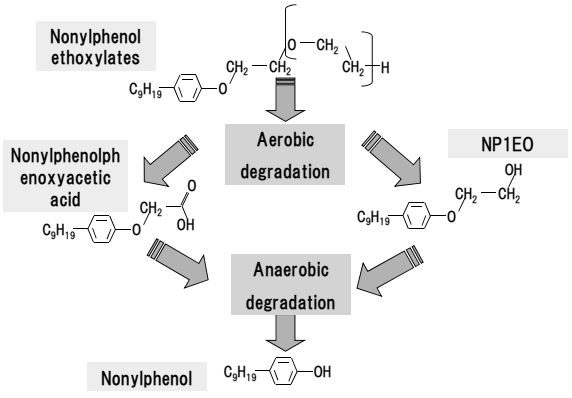
AIST

Preceding work for nonylphenol. There are 4 important risk assessment reports.

- 1996 RM-1 document for para-nonyloheol (USEPA).
- 2000 Assessment report nonylphenol and its ethoxylates (Environment Canada).
- 2001 European Union Risk Assessment Report 4-nonylphenol(branched) and nonylphenol (EU).
- 2003 USDA Human and Ecological Risk Assessment of Nonylphenol Polyethoxylate-based (NPE) Surfactants in Forest Service Herbicide Applications

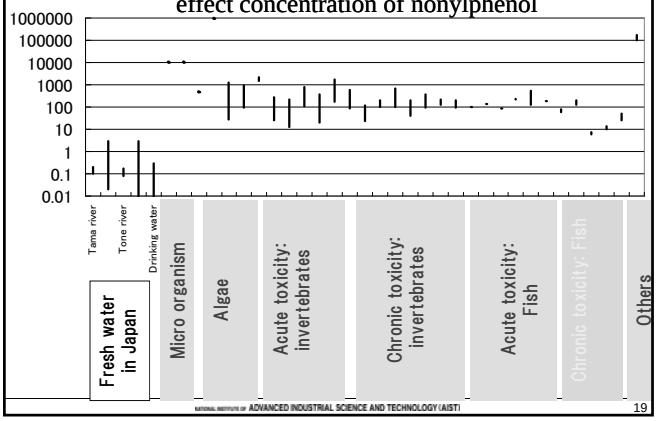
AIST

Degradation pathway of nonylphenol ethoxylates



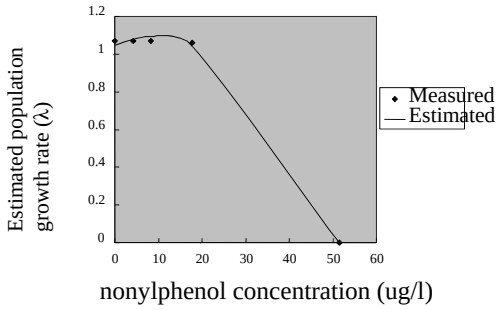
AIST

Background: Environmental concentration and effect concentration of nonylphenol



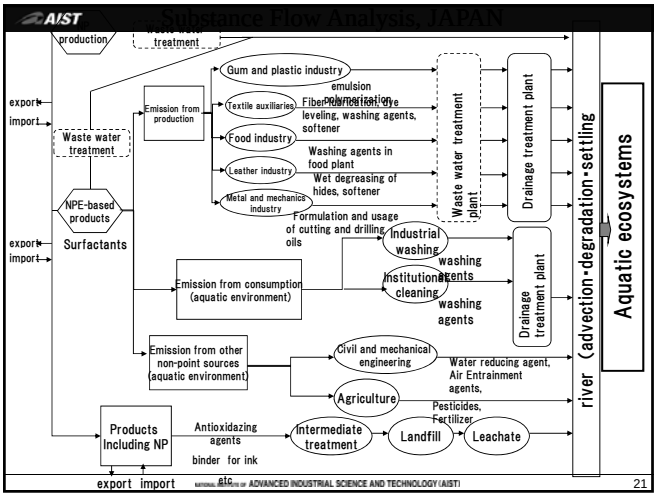
AIST

We constructed dose response relationship between nonylphenol exposure and population growth rate of Medaka based on the population dynamics model (Lin & Tokai, 2005)



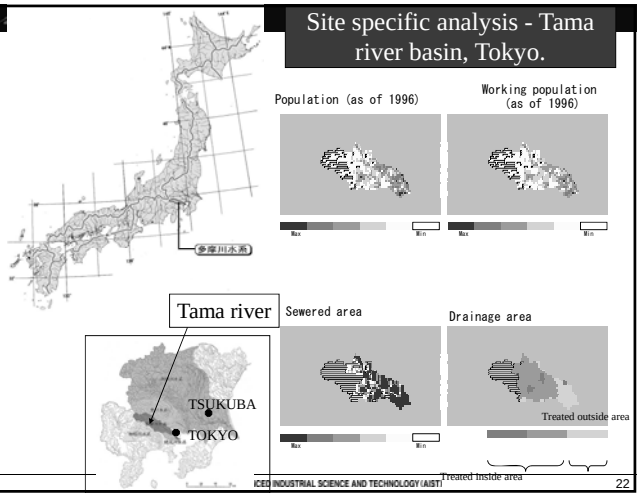
AIST

Substance Flow Analysis, JAPAN



AIST

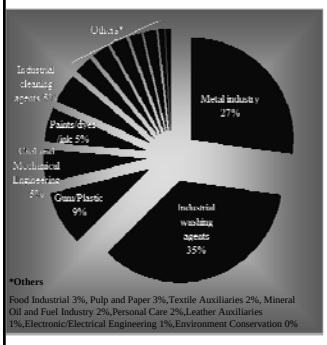
Site specific analysis - Tama river basin, Tokyo.

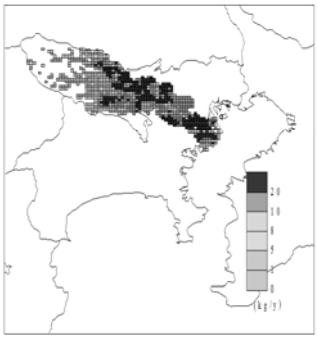


AIST

NPE Usage at Tama river basin

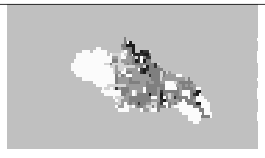
Allocation of NPE: industrial washing agents at Tama river basin





AIST

Typical profile obtained in winter and summer season, Tama river basin.



(a) Winter as of 1999/11/01/15

(b) Summer as of 1999/07/15

The upper figure is the concentration profile in winter. Because of low degradation conditions, relatively high concentration is obtained compared to the estimation in summer season (below).

AIST

Evaluation of risk management options

- Cost estimation
  - #1: Substitution
  - #2: Marginal cost for on-site wastewater treatment
    - 4 US$ (\500 yen)/BOD-kg (Estimation based on the METI, 1970-2002).
  - #3: Marginal cost for off-site wastewater treatment
    - 40 US$(\5000 yen)/BOD-kg (Estimation based on the City of Tokyo, 2000)
- Risk
  - Estimate excess probability for population growth rate or margin of exposure.

AIST

Results

		BAU	#1	#2	#3
Cost	(1,000,000Yen)	—	75.0[a)]	109.5[b)]	2,795[c)]
Risk	a)NPnEO (mg/m^3)	8.39	5.88	4.22	6.79
	b)Excess probability to population -PNEC	0	0	0	0
	c)Margin of Exposure, average	90.4	129.1	178.9	90.5
	d) Margin of exposure, 95%value	39.8	56.8	78.9	39.9
⊿risk, risk expressed as d)		1	0.70	0.50	0.99
Cost／risk		—	107	219	2,823

AIST

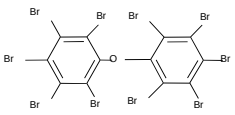
Remarks on nonylphenol

- The most susceptible effect was considered to be fish chronic effect from eco-toxicological profile. Considering this, we carried out risk assessment based on population level responses.
- As an illustrative purpose, quantitative comparison in terms of risk benefit was made. Among three scenarios, substitution and on-site treatment seems to be beneficial compared to off-site treatment.

AIST

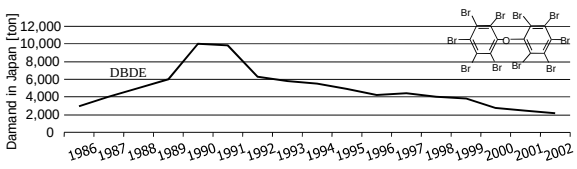
Decabromodiohenyl Ether (DecaBDE)

It took about 10 years to carry out risk assessment in EU. Very good flame retardant, but some of risk concerns still exist and industry people continues monitoring work (Deca-Monitor Project).



AIST

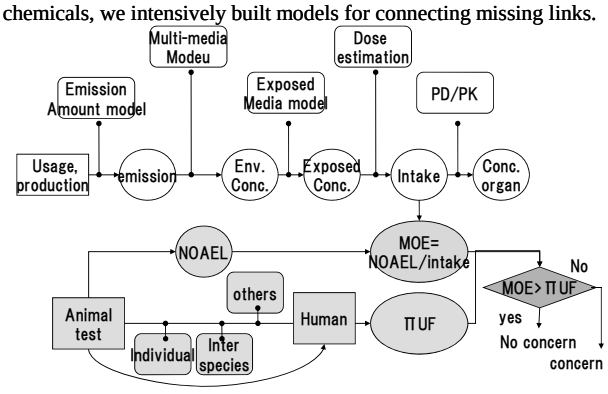
DecaBDE has been using as flame retardant such as TV back cover, carpet, etc. To quantify risk of this substance, we need to know the product chain including DecaBDE such as production to waste stage.
Recent studies tell us new findings such as behavioral effect and debromination of DecaBDE into more toxic congeners.



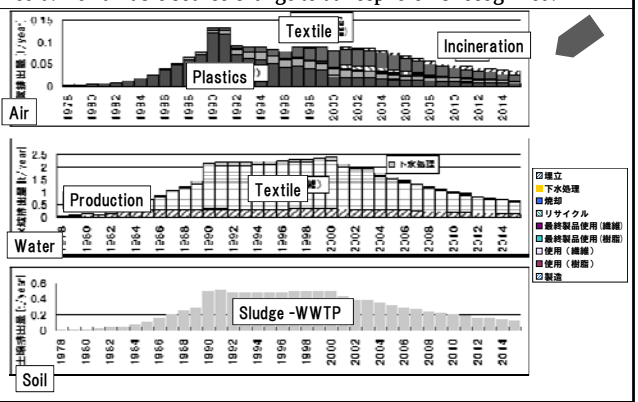
Kagaku Kogyo Nippo

AIST 化学物質リスク管理研究センター (CRM)

Overview of the analysis. Because of data poor situation of this chemicals, we intensively built models for connecting missing links.



Estimation of emission amount of DecaBDE to each environmental media. Remarkable source change to atmospheref is recognized.



AIST

Fate analysis through multi media environmental model

- **Mass balance**

$$\begin{cases} \frac{dM_{air}}{dt} = I_a - (k_{a1}+k_{a2}+k_{a3}+k_{a4})M_{air} + k_{w,a}M_{water} + (k_{s4}+k_{s5})M_{soil} \\ \frac{dM_{water}}{dt} = I_w + k_{a,w}M_{air} - (k_{w1}+k_{w2}+k_{w3}+k_{w4}+k_{w5})M_{water} + (k_{se2}+k_{se3})M_{sed} \\ \frac{dM_{sed}}{dt} = (k_{w4}+k_{w5})M_{water} - (k_{se1}+k_{se2}+k_{se3})M_{sed} \\ \frac{dM_{soil}}{dt} = I_s + k_{a,s}M_{air} - (k_{s1}+k_{s2}+k_{s3}+k_{s4}+k_{s5})M_{soil} \end{cases}$$

- **Speciation**
  - AIr
  - Water
  - Sediment
  - Soil

$$f_{ap} = \frac{C_{junge} \cdot S_a}{VP_L + C_{junge} \cdot S_a}$$

$$f_{wp} = \frac{K_{OC} \cdot OC_{ss} \cdot SS}{1 + K_{OC} \cdot OC_{ss} \cdot SS}$$

$$f_{wp} = \frac{(1-\theta_w) \cdot K_{OC} \cdot OC_w \cdot DEN_w}{\theta_w + (1-\theta_w) \cdot K_{OC} \cdot OC_w \cdot DEN_w}$$

$$\begin{cases} f_{sa} = \frac{\theta \cdot K_{aw} + \phi + (1-\theta-\phi) \cdot K_{OC} \cdot OC_{so} \cdot DEN_{so}}{\theta \cdot K_{aw} + \phi + (1-\theta-\phi) \cdot K_{OC} \cdot OC_{so} \cdot DEN_{so}} \\ f_{sw} = \frac{\theta \cdot K_{aw} + \phi + (1-\theta-\phi) \cdot K_{OC} \cdot OC_{so} \cdot DEN_{so}}{\theta \cdot K_{aw} + \phi + (1-\theta-\phi) \cdot K_{OC} \cdot OC_{so} \cdot DEN_{so}} \\ f_{ss} = \frac{(1-\theta-\phi) \cdot K_{OC} \cdot OC_{so} \cdot DEN_{so}}{\theta \cdot K_{aw} + \phi + (1-\theta-\phi) \cdot K_{OC} \cdot OC_{so} \cdot DEN_{so}} \end{cases}$$

AIST

Critical path of DecaBDE

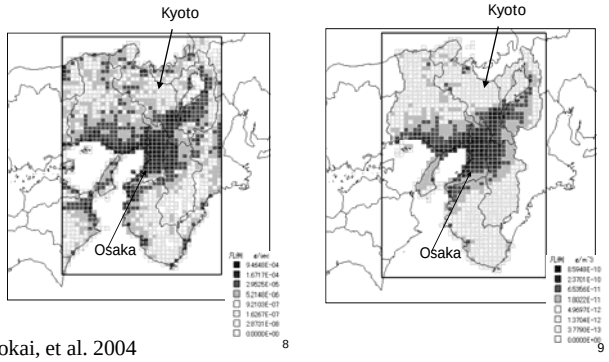
99 % or more of DecaBDE in air is adsorbed onto particles. Therefore through deposition of DecaBDE from air onto the land surface, the pathway through plant, live stocks to human is considered to be critical.

Also 99% or more of DecaBDE in water is adsorbed onto suspended solid matter. Then these suspended solid matter settles to the sediment.

AIST

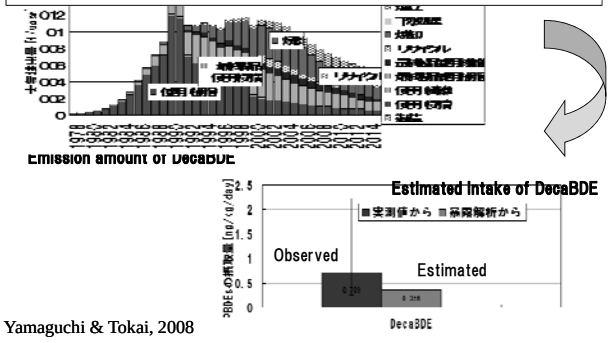
DecaBDE emission to atmosphere allocated 5km^2.

DecaBDE in outdoor



Tokai, et al. 2004

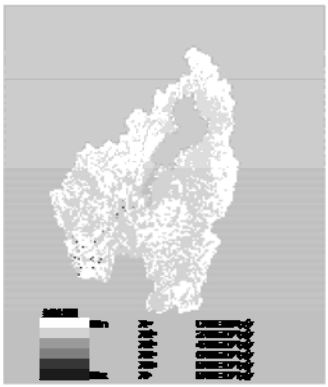
Estimation of intake of DecaBDE through environmental media. Estimated intake is relatively good agreement with observed data.



Yamaguchi & Tokai, 2008

DecaBDE emission amount to water, Yodo River basin by AIST-SHANEL ver. 1.0.

Period:
2003/1/1～12/31
Emission:
•point source(WWTP)
0.0003t/year
•nonpoint source
Direct discharge, factory
0.00215t/year
Indirect discharge, factory
0.00382t/year
・The Emission amount of DecaBDE is allocated in 1 km^2.

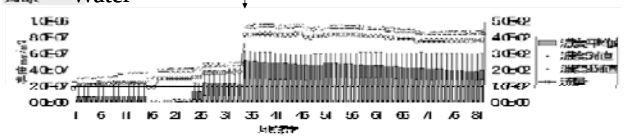


Tokai, et al. 2008)

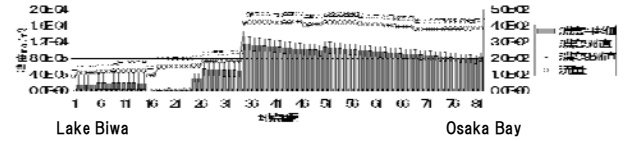
Longitudinal distribution of DecaBDE in Water Yodo River.

Katsura River (This river flow through City of Kyoto)

Water



Sediment



Lake Biwa Osaka Bay

Tokai, et al. 2008)

Talk outline

1. Overview of our research project of chemical risk assessment at CRM '01-'06.
2. Two case studies of risk and exposure assessment from our research project.
3. Implications of monitoring, modeling for better risk management.

Implications of monitoring and risk assessment

- For better risk management, we need to quantify the risk of chemicals. Though, risk can be derived quantitatively from hazard times exposure, we need relevant data. As far as relevant data is enough we can carry out risk assessment.
- Our research projects are based on the open model strategy. This is the best way not only to propagate our research tools for potential users but also to share experience on data estimation.

Implications of monitoring and risk assessment (continues)

- To better chemical risk management, we can not avoid data poor situation in risk assessment, because there are many unknown situations, such as toxicity, and exposure patterns.
- Especially for exposure analysis, estimation by validated model is powerful tool. And this might be the only way to overcome the data poor problem. Models without validation can not be used for risk assessment. In this sense, good combination of monitoring and modeling work is the key factors for risk assessment.

Thank you for your attention.

NIMD Forum 2008

Mercury Recycling and Environmental Monitoring for a Sustainable Society

発行　環境省　国立水俣病総合研究センター
Published by National Institute for Minamata Disease, Ministry of the Environment, Japan

〒867-0008　熊本県水俣市浜 4058-18
TEL: 0966-63-3111
FAX: 0966-61-1145
http://www.nimd.go.jp
kokusai@nimd.go.jp

4058-18, Hama, Minamata, Kumamoto 867-0008, Japan
TEL: +81-966-63-3111
FAX: +81-966-61-1145

問い合わせ先：国際総合研究部
For inquiry: Department of International Affairs and Environmental Sciences