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Current Issue on Mercury Pollution in the Asia-Pacific Region

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Preface

On behalf of the National Institute for Minamata Disease, which is hosting this NIMD Forum 2006 (Second), titled "The Current Issue of Mercury Pollution in Asia-Pacific Region," I would like to offer a few words of greeting to you all.

The occasion for the start of these NIMD Forums was the reorganization of the National Institute for Minamata Disease in 1996, and the establishment at that time of a new department, the Department of International Affairs and Environmental Sciences. Today more than ever the National Institute for Minamata disease, centered on our international and multidisciplinary departments, is working with the problem of mercury pollution in all parts of the world. We started the NIMD Forums in 1997 with the aim of inviting leading researchers from around the world such as yourselves, who are at the forefront of mercury research, to come together and make presentations on the latest research in the field. The forums also serve as a place for interaction between researchers at our institute and forum guests. We are pleased to note that this year will be the 8th NIMD Forum.

The aim of this year’s NIMD Forum, as we can see by its title, is to share and discuss the latest research findings on the problem of mercury pollution in the Asia Pacific region, among those on the front lines of this problem. The striking economic development of the Asia/Pacific region in recent years has been accompanied by the sound of warnings with regard to various pollution problems. In the field of mercury pollution, the situation has become alarming. It is our hope that this forum will serve as an occasion for comprehensive thinking about the problem of mercury pollution in its various forms, including in water systems, the atmosphere, and soil, while keeping in mind the health impacts on people living in affected areas. We look forward to your presentations and active discussion of these important matters. I and all of the researchers here at the National Institute for Minamata disease also wish sincerely for lively interactions with you, our guests, and the building of future ties.

November 28, 2006

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Interventions to Reduce Mercury Pollution in Artisanal Gold Mining Sites: Lessons from the UNDP/GEF/UNIDO Global Mercury Project

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ABSTRACT

As gold has risen in value and artisanal gold mining has increased in many countries, there has been an increasing need for sustainable development models that promote environmental protection while enhancing the contribution of this activity to poverty alleviation. Artisanal mining provides a critical source of income for an estimated 15 million poverty-driven miners around the world, mainly in Africa, Asia and Latin America. However, its environmental impacts are often extensive, with mercury pollution posing major threats to human health and diverse ecosystems. 1000 tonnes of mercury are polluted annually into the environment due to mercury misuse in artisanal gold mining. This represents approximately 30% of the world's anthropogenic source of mercury pollution. Mercury is a potent toxin that damages the brain and kidneys, and is particularly dangerous for developing babies and small children. This paper reviews community development models pioneered by local community practitioners and international experts as part of an initiative by the United Nations Industrial Development Organization, which can help to overcome environmental, health, social and economic challenges. We discuss the introduction of various technical options, from simple innovations that allow mercury containment, recycling and re-use, and also emphasize the importance of technologies of grinding and crushing that can be developed from local materials to further enhance income potential. While various past development efforts have sought to reduce mercury-related problems, we conclude that sustainable development should seek to intertwine knowledge-sharing on environmental goals with concrete ways of improving economic well-being. We demonstrate how such models of knowledge-sharing can help to catalyze local innovation, technology-sharing and community organization. We also discuss how this knowledge can be applied by governments to create capacity-building policies as well as regulations that support sustained improvement in mining standards.

INTRODUCTION

As gold has risen in value (US$ 260/oz in Mar 2001, US$ 540/oz in Mar 2006) and artisanal gold mining has increased in many countries, there has been a heightened need for sustainable development models that promote environmental protection while enhancing the contribution of this activity to poverty alleviation. In over 55 countries, artisanal mining provides a critical source of income for rural populations, especially those that have been driven out of other sectors due to failed commodity markets or agriculture conditions. In 1999, the International Labor Organization estimated that there were 15 million small-scale miners around the world (ILO, 1999), with an estimated increase to follow as a result of limited occupational opportunities in poor economies. Such mining usually involves rudimentary, inefficient and environmentally unsound forms of extraction and processing, causing extensive mercury pollution.

Global recognition of this sector has increased in recent years. Development institutions such as the World Bank have recently emphasized the significance of the sector as a contributor to poverty alleviation, resulting in the creation of the Communities and Small-Scale Mining (CASM), for example. Governments have begun to change legislation to provide formal recognition to this sector, with recent legal developments in Ghana and Tanzania within the past ten years that recognize “artisanal” mining as a distinct activity—and one that has the potential to contribute to poverty alleviation. Along with these developments in the sector, there is an ever more present need for finding new ways of improving the sustainability of the activity and decrease environmental impacts. In particular, developing efforts to reduce mercury pollution is critical. Globally, poor amalgamation practices cause as much as 1000 tonnes of mercury to be emitted into the environment per year, contaminating the air, soil, rivers and lakes (Veiga and Baker, 2004).

In this paper, we review efforts to bring technological improvement and environmental protection together in artisanal mining communities. We focus on community development models pioneered by the Global Mercury Project, which was launched in 2002 by the United Nations Industrial Development Organization (UNIDO) to promote the adoption of technologies to reduce mercury use and emissions while strengthening capacities for maximizing gold recovery. The project focuses on six countries — Brazil, Sudan, Indonesia, Laos, Tanzania and Zimbabwe. We first review the results of the environmental and health assessments conducted by the project in selected areas, which found that vapor intoxication is the main pathway of mercury exposure in mining communities, and we draw attention to risk communication and mitigation strategies. Secondly, we demonstrate how a training model for disseminating technological solutions, developed by local community practitioners and international experts, can help to overcome environmental, social and economic challenges. We discuss the introduction of various options, from simple innovations that allow mercury containment, recycling and re-use, and emphasize the importance of technologies of grinding and crushing that can be developed from local materials to further enhance income potential.

While various past development efforts have sought to reduce mercury-related problems, we conclude that sustainable development should seek to intertwine knowledge-sharing on environmental goals with concrete ways of improving economic well-being. Such models of knowledge-sharing can help to catalyze local innovation, technology-sharing and community organization. This knowledge can be applied by governments to create capacity-building policies as well as regulations that support sustained improvement in mining standards. To meet these goals around the world, we conclude that an increase in international support is vital, particularly to promote inter-national and inter-regional knowledge-sharing and capacity-building assistance.

GOLD MINING AND MERCURY: GLOBAL CHALLENGES

Artisanal and small-scale mining (ASM) is generally a practice which uses rudimentary techniques of mineral extraction and operates under hazardous conditions. Driven significantly by poverty, ASM is usually undertaken by workers with limited technical knowledge of the long-term impacts of their mining activities on the environment and on their health and/or with limited capacity to mitigate the hazards (Veiga, 1997). Ecological impacts caused by ASM activities include diversion of rivers, water siltation, landscape degradation, deforestation, destruction of aquatic life habitat, and mercury pollution (Mol and Ouboter, 2004). Direct impacts of ASM on human health can include acute mercury poisoning, silicosis, neurological and kidney damage, cardiovascular and respiratory dysfunctions, as well as injury and fatality from landslides, cave-ins, and chronic physical overexertion (Hinton et al., 2003a).

Often working in tunnels with explosives and being exposed to mercury, cyanide and other toxins, ASM provides a primary source of earnings for a rapidly growing number of people around the world, particularly in regions in Africa, Asia and Latin America where alternative sources of income are limited. According to the International Labour Organization, the number of small-scale miners worldwide increased by up to 20% between 1989 and 1999 (ILO, 1999). Estimates made more recently, in 2004 by the United Nations Industrial Development Organization (UNIDO), indicate that there are as many as 20-30 million small-scale miners in more than 55 countries, roughly equivalent to the global workforce of large-scale mining. It is estimated that 80 to 100 million people worldwide are directly and indirectly dependent on ASM for their livelihood (Veiga and Baker, 2004). As this population continues to increase, there is an urgent need to develop the capacity of small-scale miners to minimize the risks associated with mining practices in their communities and shift toward safer, cleaner and more sustainable methods.

The Global Mercury Project (GMP) was launched in 2002, by UNIDO with support from UNDP and GEF, aimed at removing barriers to the adoption of cleaner practices of small-scale gold mining. The project sought to provide a platform upon which knowledge could be generated to meet diverse community challenges. In particular, it was envisaged that the GMP would spearhead the search for opportunities to reduce negative health and ecological impacts caused by mining through a series of multi-stakeholder consultation processes and capacity-building campaigns in affected communities. Partnering with government ministries, local authorities, health organizations and miner associations, the project undertook assessments of health, ecological, social, economic, and technological factors in participating communities. This knowledge, it was hoped, could be effectively utilized to design and implement intervention strategies that target the causes of poor practice, ill health and pollution.

ADDRESSING ENVIRONMENTAL AND HEALTH IMPACTS

Due to the informality and unregulated nature of many ASM operations throughout the world, the full extent of this activity and its ecological and health impacts is difficult to determine. Gold is easily sold and traded in markets that are not dependent on the stability of local governments; consequently, is by far the most important mineral extracted by ASM in developing countries. The number of ASM *gold* miners alone is estimated at 10-15 million people, including 4.5 million women and 300,000 children (Veiga and Baker, 2004). Because mercury amalgamation is simple and inexpensive, it is the gold concentration method most used in ASM.

Mercury misuse in ASM has produced thousands of polluted sites with impacts extending far beyond localized ecological degradation, often presenting a serious, long-term health risk to individuals residing in mining regions. Amalgamation employs metallic mercury to trap fine gold, with mercury often being discharged with contaminated tailings and/or volatilized into the atmosphere. The usual practice is to burn the amalgam in a pan or shovel in open air bonfires, with the inhalation of mercury vapor posing a serious health risk. Due to inefficient techniques, an estimated two grams of mercury are released into the environment for each gram of gold recovered (Veiga and Baker, 2005). Metallic mercury is also transformed into methylmercury in aquatic systems, which becomes biomagnified in the food chain. Communities reliant on fish, especially carnivorous fish, as a primary food source are particularly susceptible to accumulation of high levels of methylmercury and to neurological damage in cases of acute intoxication (Webb et al., 2004; Ikinguara and Akagi, 1996; Mergler 2002). Methylmercury can also cause sterility and is easily transferred from pregnant women to their fetuses, with effects ranging from spontaneous abortion to neurological symptoms in the child (WHO, 1990).

In 1990, UNIDO began coordinating international efforts to provide technical assistance to small-scale miners, promoting the replacement of low gold recovery, high mercury consuming and discharging practices with more environmentally sound and high-yield gold extraction alternatives. Following a gold rush in developing countries in the 1980s and early 90s, it was acknowledged that both regulatory (top-down) and community capacity-building (bottom-up) strategies needed to be pursued. Working with governments and community stakeholders from Venezuela, Ghana and the Philippines, UNIDO carried out programs to develop local capacity to assess and minimize mercury emissions caused by mining and provide high-level technical advice to government officials to design regulations and institutional reforms. In 2001, with financial assistance from the Global Environment Facility (GEF), UNIDO identified hot spots with the potential for affecting international waters due to especially high levels of mercury pollution in streams and rivers. These efforts culminated in the solidification in August 2002 of a longer-term initiative, the GMP, supported by GEF, the United Nations Development Program (UNDP), and UNIDO, to demonstrate ways of overcoming barriers to the adoption of strategies that limit mercury emissions in ASM.

LESSONS FROM SIX PILOT COUNTRIES

The GMP currently focuses its efforts in six main pilot countries, each representing diverse ecosystems: Brazil (Amazon), Lao PDR (Mekong), Indonesia (marine environment), Sudan (Nile), Tanzania (Lake Tanganyika) and Zimbabwe (Zambezi). The project is complemented by a suite of ongoing activities that are supported through participating countries' resources and/or bilateral programs. As a capacity-building initiative that combines expertise in mining engineering, health promotion, economic development, and environmental planning areas, the GMP seeks to provide a strong link between researchers and practitioners to implement solutions. The specific goals are 1) to reduce mercury pollution of international waters by emissions emanating from small-scale gold mining; 2) to introduce safer and cleaner technologies for gold extraction and to train people in their application; 3) to develop capacity as well as the policy, regulatory and economic mechanisms that will enable the sector to minimize mercury pollution; 4) to introduce environmental and health monitoring programs; and 5) to build capacity of local laboratories to assess the extent and impact of mercury pollution.

The countries participating in the GMP were selected based on the importance of ASM to their populations, preliminary assessments of mercury use, and support of the national and regional governments for capacity-building activities. Also a major factor was the potential of international waters to be impacted by mercury from mining. Most ASM activities within the six GMP countries are conducted within basins of major ecological significance and that cross geographical boundaries, e.g., basins of the Amazon, Nile, Lake Tanganyika, Zambezi River, and Mekong River. As such, the negative environmental impacts within these basins can affect many countries including those with ASM activities as well as neighbouring countries. Project assessments found that gold mining activities in Brazil dump nearly 40 tons of mercury annually, with significant pollution risks to Amazon Basin, the largest drainage system in the world which also constitutes the largest reserve of biological resources. Nearly 150 tons of mercury is dumped annually into the environment in Indonesia, affecting the Java Sea and nearby waters (Veiga and Baker, 2004). Little investigation had been previously undertaken to address the mobility of mercury emanating from small-scale mining through international waters, and the GMP represents the first effort to implement a global action plan.

Following its launch, the GMP conducted exhaustive consultations with stakeholders to formulate an appropriate community assessment and capacity-building agenda—with numerous Task Force Meetings held in each of the countries. These reinforced the widely held view that implementation of technical solutions required detailed knowledge of the cultural, social, economic and organizational context on a site-specific basis in addition to a thorough understanding of mercury exposure pathways and mobility through the diverse ecosystems. Numerous studies have noted that a major barrier to the adoption of cleaner mining practices is that the impacts of mercury misuse are complex and difficult to see immediately, thus masking the dangers (Hilson, 2002a; Hinton et al., 2003b). Another significant barrier is that many small-scale miners are unaware of cost-effective ways to eliminate the hazards. Recognizing these barriers as nuanced and widespread, the participants generally agreed that, to develop effective site-specific training programs, a variety of expertise was needed to create synergy in the process. As well, sociological surveys enabled communities to describe their customs, share their knowledge on social, environmental and health aspects in the area, and give feedback on the project before further assessments and training programs were undertaken.

Information on the effects of mercury on human health exists but is inadequately disseminated in developing countries (Hilson, 2002b). A key early accomplishment of the GMP was the training of a cadre of regionally-based public health personnel in the assessment of clinical signs and symptoms of mercury poisoning and methods of improving environmental health in mining areas. In each country, these partnerships were strengthened while integrated health and environmental assessments were conducted in the project sites, using GMP protocols that provided a framework for combining biogeochemical, socio-demographic, and technical analyses (Veiga and Baker, 2004). Results showed that symptoms of mercury intoxication are especially widespread in miners in Zimbabwe, Indonesia, Brazil and Tanzania, with alarmingly high levels of intoxication found in miners in all six countries who spent significant amounts of time burning mercury amalgams. Neurological disturbances such as ataxia, tremors and coordination problems were found to be common among this group. In Kadoma, the main project site in Zimbabwe, 70% of miners (69% of child miners) were intoxicated, many of whom showed tremors, a typical sign of mercury-induced central nervous system damage. With extremely high mercury concentrations in breast-milk samples from nursing mothers in GMP communities, infants are especially at risk. In addition to problems from mercury vapour, the assessments found that mercury methylation is a severe ecosystem hazard in project sites in Brazil, Indonesia and Zimbabwe, with particularly harmful impacts on the fish-eating communities where mercury accumulates in aquatic biota.

Technical and socio-economic studies in all participating communities assessed current equipment and practices, needs of the miners, and accessibility of new equipment. In all GMP communities except those in Brazil, women and children engage in open-air mercury amalgamation at home, with entire families exposed to mercury vapour. Combined use of mercury and cyanide in mineral concentration was also identified as particularly dangerous and widespread, and practices that involve the amalgamation of whole ore (all the ore mined) also caused excessive amounts of mercury to be used and leaked into the surrounding soils and streams.

SHARING KNOWLEDGE FOR DEVELOPMENT

1. Meeting Community Concerns

Between March of 2005 and 2006, a series of international workshops was held in all six countries to determine how to transfer knowledge effectively from the assessments into the community intervention phase of the project. This phase focuses on capacity building - training and demonstrating solutions to miners, families, and authorities - with emphasis on affordable and easily accessible ‘homemade’ equipment, such as amalgamation retorts (made of kitchen-bowls) which contain mercury vapour and decrease mercury use in the amalgamation process (Babut et al., 2003). During this phase, GMP efforts aim to reduce mercury use and promote safer, healthier and more cost-effective mining practices; strengthen community organization; improve access to equipment through micro-finance programs; enhance participation of miners in environmental planning processes; and assist authorities in the implementation of needed regulations and reforms.

Due to the importance of amalgamation to the ASM process and their immediate livelihood, convincing miners to eliminate mercury use because of health hazards is difficult. As one miner mentioned at a meeting in Brazil, “Mercury is a problem, but we also depend on it.” Moreover, particularly in the case of Africa, lack of sanitation, widespread infectious diseases and limited access to health care have resulted in generally poor health conditions in ASM communities, such that any program directed exclusively at reducing the comparatively invisible health impacts from mercury is hard-pressed to garner local interest. As such, the capacity building approach adopted by the GMP does not focus on mercury issues alone, but rather on the myriad of intertwined health, environmental and socio-economic challenges in these mining communities.

It is worth noting that previous projects on mercury management in developing countries have tended to adopt frameworks based on hazard awareness, technical training *or* regulatory changes, with short-term agendas and limited resources for integrating multiple disciplines and strategies

(Hilson, 2002a). Moreover, authorities have tended not to combine health and environmental planning processes in mine sites and are often unfamiliar with ways to support educational programs on the ground (Hinton et al., 2003a,b). Seeking to better connect miners, field practitioners, experts and authorities, the GMP model involves team members with diverse expertise in community development disciplines to bridge diagnostic, risk communication and knowledge translation models.

The collaboration to build sustainable solutions through a transdisciplinary approach proved critical in developing the GMP community training curriculum (Table 1), which recognizes that each community faces different challenges and that the need to alleviate poverty and address malaria and HIV AIDS is primary in many GMP communities where mercury pollution is also a problem. The project's multi-faceted training curriculum is designed to remove barriers to the adoption of cleaner practices by:

- improving miners' income through more efficient gold recoveries
- enhancing access to equipment and ability to fabricate local equipment
- strengthening business keeping skills
- enhancing access to microcredit
- strengthening technology-sharing and community organization (e.g. cooperatives)
- demonstrating the benefits of containing mercury emissions (economic and environmental health)
- demonstrating ways of reducing mercury hazards as well as other occupational health and environmental problems
- implementing disease mitigation and health care measures (vaccinations, HIV prevention controls, prenatal and postnatal care, etc)
- improving sanitation and management of waters

Table 1: GMP Education and Training Program in Small-Scale Mining Communities: Modules for the Train-the-Trainer Process

TRAINING MODULES	KNOWLEDGE FROM COMMUNITY PRACTICE	KNOWLEDGE FROM ACADEMIC DISCIPLINE
Module 1: How to Produce More Gold	Underground mining methods: winches, windlasses, Wheelbarrows dewatering	Mining Engineering
	Mine safety: ground stability; ventilation; timbering; personal protective equipment	Mining Engineering and Occupational Health and Safety
	Alluvial mining methods: control of siltation; gravity concentration	Mining and Mineral Processing Engineering; Watershed Management
	Mineral processing methods: liberation and concentration of gold: crushing and grinding; gravity concentration; safe extraction with mercury	Mineral Processing Engineering
Module 2: How Mercury Makes Us Sick	Pathways of exposure: metal and methylmercury; vapor, skin, ingestion.	Environmental Toxicology
	How to recognize symptoms	Healthcare
	Effects on children and women (esp. pregnant women)	Epidemiology; Gender Studies
Module 3: How to Use and Re-use Mercury Safely	Safe extraction of gold from concentrate: amalgamate concentrate--not whole ore.; use amalgamation barrels; properly dispose of amalgamation tailings;	Mineral Processing Engineering; Occupational hygiene
	Burning amalgam in retorts to contain vapor (outdoors and away from houses)	Mineral Processing; Occupational hygiene
Module 4: How to Make More Money	Participating in the formal economy: how to become a legal miner; how to secure mineral rights	Law, Economics and Sociology
	Managing money: double entry bookkeeping	Business and Accounting
	Selling gold for a better price: government and cooperative gold buying/marketing schemes	Economic Policy
	How to access more efficient equipment: micro credit and renting	Economics and Business
	Alternate forms of organization: how to form co-operatives and partnerships	Business and accounting; Political Science
Module 5: How to Protect Water Supplies and Improve Sanitation	How mercury behaves in water: siltation and mercury transport; bioavailability of metal mercury; methylmercury	Hydrology and Toxicology and Chemistry
	How to manage animal and human waste: bacteria and parasites; how to build toilets	Water and Sanitation Engineering;
	How to access clean drinking water: hydrological cycle; the water table; rainwater management	Hydrogeology; Integrated Watershed Management
	How to manage mining waste: tailings impoundment; reclamation	Environmental Policy; Civil Engineering; Agricultural Science
Module 6: How to Prevent HIV, Malaria and other Diseases	Prevention of HIV transmission: condom use; empowerment of women; safe use of scarification implements	Healthcare; Epidemiology; Gender Studies; Anthropology
	Malaria: use of netting and other preventative measures; how and where to obtain treatment	Healthcare; Epidemiology
	Mercury poisoning, tuberculosis and other diseases	Healthcare; Toxicology

Training also encourages strengthening community organization to legalize miners who do not currently possess land rights and to adopt changes collectively. Finding innovative ways to promote participation is fundamental to enable affected populations to initiate solutions in a way that can be sustainable and maximize limited resources. The first phase of the GMP emphasized participatory processes in developing capacity-building models that are country-specific and community-specific, wherein community members identified what equipment is needed most and what techniques should be demonstrated. The second phase of the project seeks to involve as many community members as possible in the training workshops and to encourage participation of new players. To reach broad audiences, communication methods were locally determined to build upon the cultural roots and institutional strengths of the communities, such as using soccer events, music, street theatre and circuses to attract people to training workshops; education events at schools and through religious organization; and radio and television campaigns to promote awareness of mining issues as well as GMP activities.

Enhancing participation is especially vital throughout the implementation of the Transportable Demonstration Units (TDUs), which provide platforms for community training on improved technological options for mining and mineral processing as well as environmental health and safety. Parallel to the activities of the TDU education center, media campaigns are designed to draw people to these events and address the critical misperception that mercury is not dangerous because, like HIV-Aids, its toxic effects are not immediate. GMP participants noted that the success of many previous training initiatives was limited because they relied upon permanent, immobile structures for technological demonstrations which were not adaptable to new locations and thus restricted participation. Heeding these lessons and the fact that artisanal miners are typically mobile and transient, the GMP mobile units were designed to travel to different highly-populated zones to maximize community participation and bring solutions to miners where they work.

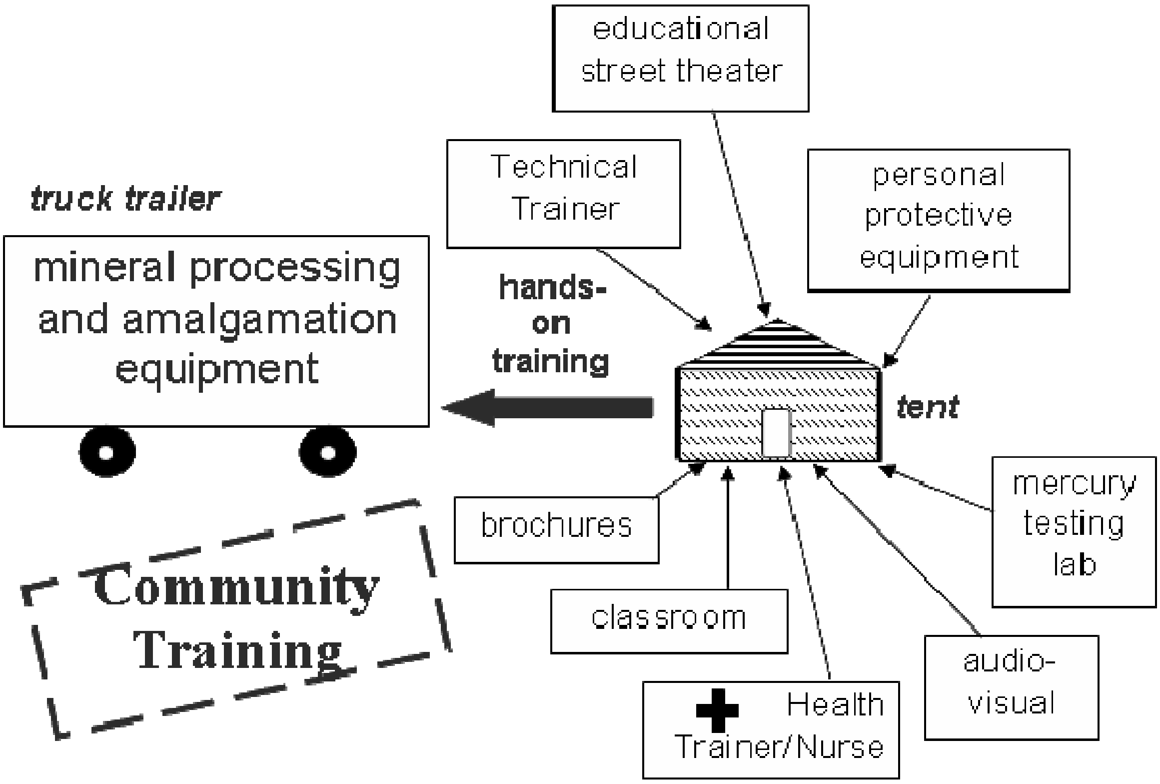

Figure 2: Design of Transportable Demonstration Units (TDUs)

The consultation processes revealed that gender-specific approaches are indispensable. The recognition of the important role of women in ASM has taken on considerable importance as more than 30% of the world's artisanal miners are women, the majority of whom work in the mineral processing aspect - including amalgamation with mercury (Hinton, 2003). As women are also predominantly responsible for food preparation, they are in an excellent position to address health risks associated with consumption of mercury-contaminated foods. Because women are often associated with transporting and processing materials as opposed to digging, they are not always identified as “miners” (Sasapu and Crispin, 2001; Hinton et al. 2003a), and thus there is an especially important need to promote the inclusion of women in community planning processes at miner association workshops and other venues. GMP efforts focus on training women specifically, reducing exposure risks to women (especially pregnant women) and their families, and promoting gender equity in community planning.

2. Sharing Knowledge for Technology Transfer

Although the international price of mercury tripled between 2004 and 2005, mercuryremains widely used by small-scale miners. Observations and discussions with miners reinforced the need for focussing attention during training activities on simple ways of reducing mercury emissions. In a pilot project conducted in 2005 in Manica District, Mozambique, the GMP trainers performed with retorts showed that mercury emissions can be contained in such a way that allows 95% of the mercury to be reused. Miners expressed that the relatively inexpensive nature of this technology made it feasible. We discuss this demonstration experience below.

Various types of retorts can be used to reduce mercury emissions. Retorts allow for the heating of the amalgam in a chamber, releasing mercury that condenses as it passes through the cooling pipe thereby allowing it to be collected and reused later. In the first demonstration, a kitchen-bowl retort was used (consisting of two salad bowls - one bottom and one top as the cooling chamber) and a small stainless steel cup (amalgam chamber) where the amalgam is introduced. (If ordinary steel is in contact with retorting amalgam, rather than stainless steel, the gold becomes brown, reducing its market value). A glass bowl was used as a cover, so that the miners could directly see the result of the amalgam transformation by visual observation of the color change (Figure 3). Miners indicated, however, that the time taken to burn the amalgam and cool down the retort was longer than expected (20 minutes for 2 grams of amalgam) basically because it is difficult to cool down the glass cover. A substitute kerosene burner (stove) was purchased to speed up the retort-burning time and steel bowls used as the cover for rapid cooling with water. The entire retorting and cooling process for 6g of amalgam took 10 minutes. The retorts are sealed with wet sand around the cover. The amalgam is heated in a bonfire and mercury is evaporated to be condensed on the surface of the cover; then mercury droplets fall on the sand.

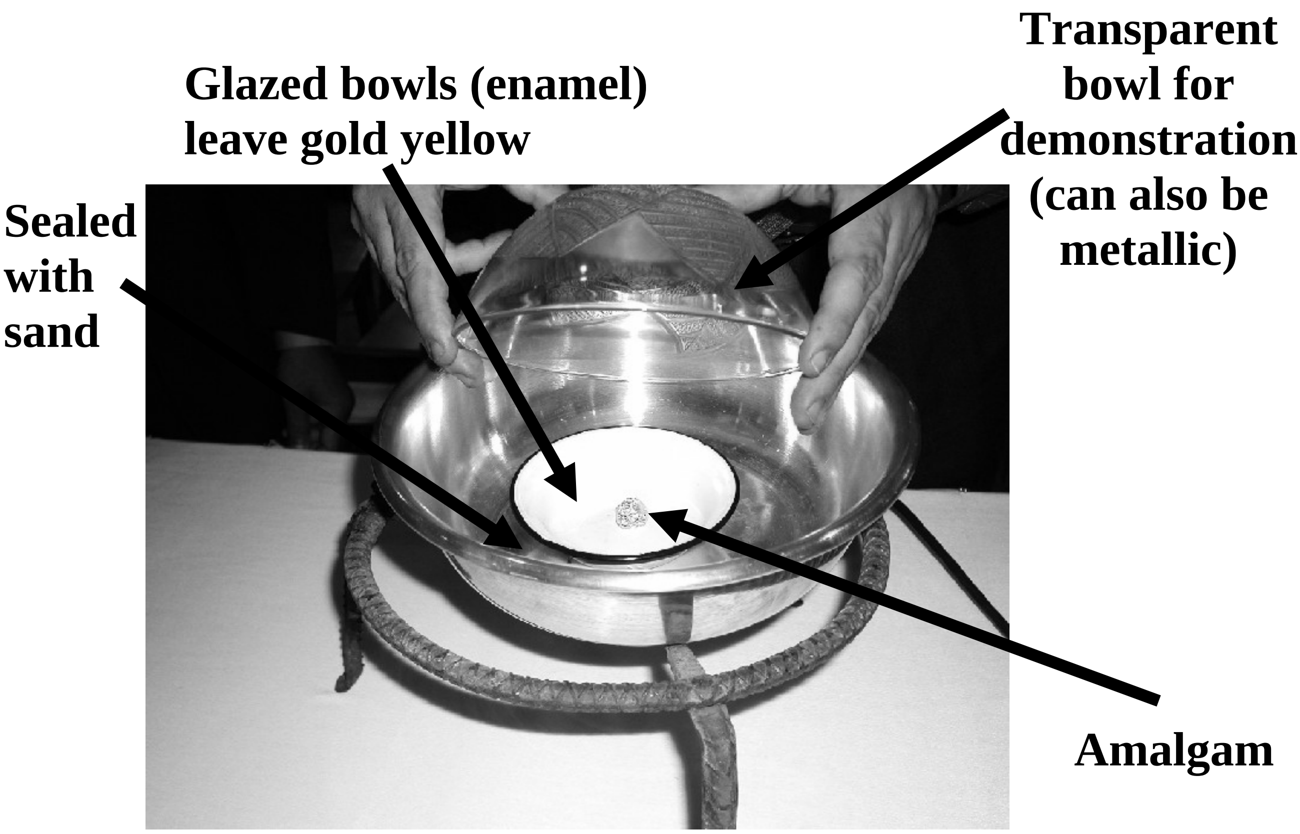

Figure 3: Retort for Containing Mercury Releases

A home-made retort built with standard plumbing water pipes was also demonstrated (Figure 4). The distillation chamber was made by connecting an end plug into which the amalgam is placed (amalgam chamber) to a 1/2” plumbing pipe. The size of the retort was 1.5” (and can vary from 1/2 to 3”). The condensation tube was 50cm long and curved downwards through an elbow bend to permit good condensation of gaseous mercury wit hout the use of a coolant, with the tip of the tube extended into the water in the plastic bowl. The galvanized steel pipes and connections were previously burned over the kerosene stove to remove the inherent zinc layer on the steel. After demonstrating the use of retorts, the mercury condensed in the sand was panned and recovered using a simple method in which droplets of mercury are transferred to a plastic recipient with a saline solution. The process involves connecting mercury droplets to a positive pole of a flash-light battery, the negative pole remaining in the saline solution, such that the superficial oxidation layer of the droplets is removed and the mercury then agglomerated.

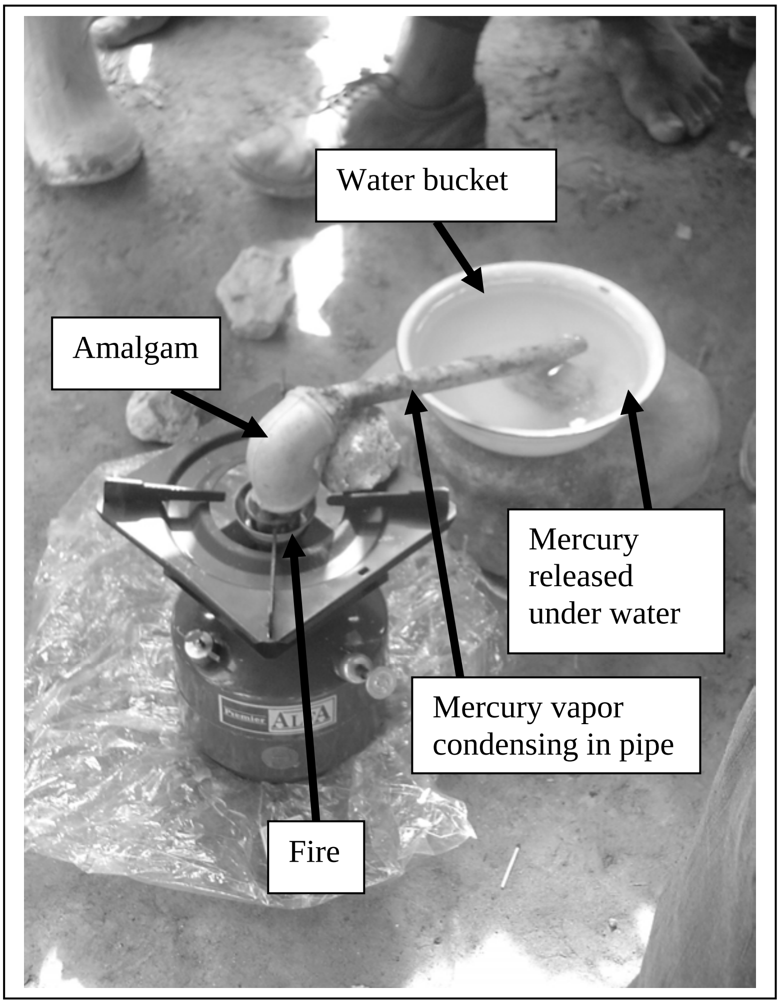

Figure 4: Home-made Pipe Retort

This experience established that retorts could be made easily and inexpensively and that all materials needed to fabricate these retorts were easily obtainable from local mechanical, electrical and general hardware suppliers in the local towns. Materials and equipment that were not available off the counter could be easily fabricated in numerous engineering workshops in both towns. The total cost for making one kitchen bowl retort (metallic) was US$3.30. The cost for making one home-made pipe retort was US$4.80. The 24 organizing members of the miners association in Manica District, representing 3,764 miners in the area, agreed that the solutions brought to them were beneficial, reasonably inexpensive (in view of the economic benefits from re-using mercury), and easy to implement. Trainers were chosen by the association who proceeded to promote this solution to other miners.

Mercury analyser breath tests of miners and community members showed a pre-retort use average mercury level of 8.23µg/m³. Three miners who were regular amalgam burners returned the highest breath mercury levels on the Lumex Mercury Analyzer instrument. Mercury levels of about

30µg/m³ were recorded in the air as soon as these three severely intoxicated miners were close to the Lumex (likely due to the contamination in their clothing).3 Without the three most contaminated miners, the average pre-retort use breath Hg test was 3.12µg/m³. The average air Hg levels in the vicinity of miners was around 1µg/m³. Air in the village contained an average mercury contamination level of 0.4µg/m³.

Prior to the use of retorts, the levels of mercury in the air were measured between 0.30 and 0.60µg/m³, with an average of 0.412 µg/m³. In the air surrounding the kitchen bowl retorts, the average level of Hg measured was 40.87, 3.39, and 0.62 µg/m³ respectively for 0.1m high, 1m high, and a person's nose level (~2m from retort). In the air surrounding homemade pipe retorts, the average level of Hg measured was 35.67, 2.11, 1.93 µg/m³ respectively for 0.1m high, 1m high, and a person's nose level (~2m from retort). The WHO 1991 recommended TWA exposure limit for metallic Hg is 25 µg/m³ for long-term exposure (WHO 1991). The National Institute for Occupational Safety and Healthi has established a recommended exposure limit for mercury vapour of 50µg/m³ as a TWA for up to a 10-hour workday and a 40-hour workweek (NIOSH, 1992). Malm measured up to 60,000 µg/m³ of Hg in air when amalgam was burned in open pans in an ASM operation. When retorts were used, this concentration dropped to as low as 10 µg Hg/m³. Thus, the retorts appear to be highly effective in reducing mercury exposure. Moreover, the use of the retorts allowed the miner to re-use 95% of the mercury.

PROMOTING SUSTAINABLE LIVELIHOODS

The TDUs, while empowering miners to improve their practices individually, will also serve as forums in which community members can collectively plan safer, cleaner and more cost-effective practices through equipment-sharing and revenue-sharing arrangements. Although attempts to create formal business cooperatives had generally not been made in mining in the participating countries, this approach may also prove valuable in various communities where individuals have little money to invest in equipment and receive exceptionally low prices for their gold. Moreover, it will be pivotal that introduction of grinders, crushers, other equipment pieces be accessible. Currently, women are often delegated the role of crushing rocks by hand (such as in Manica District, Mozambique), causing inefficiency and severely arduous labour conditions. Innovative solutions need to be seized in order to maximize the earning potential of miners, many of whom live far below the poverty line. In this regard, the GMP team is currently discussing with communities about the technologies that would be most accessible and suitable to them through a series of demonstration and training workshops. Efforts to remove barriers to access (e.g. through the promotion of micro-credit) are also critical to meet these goals.

A process of discussions with governments has yielded positive steps. In the 6 pilot countries, the GMP team has engaged the governments to address the issues by pursuing policy development strategies that address both regulation for ASM and assistance for ASM. Based on the Health and Environmental Assessments that were completed by the GMP, it is concluded that regulatory measures should be instituted to address mercury hazards, particularly to require the use of retorts, to require the retorting be done in centralized locations (away from water bodies, and away from villages), and to require that licensing be mandatory for retorting centres. Assistance measures, meanwhile, are necessary to support miners through technical assistance, education services, and to encourage legal trading of gold in markets that will allow miners to earn fair wages.

THE WAY FORWARD

ASM is often characterized by extensive negative environmental, health and socioeconomic impacts. However, ASM also provides livelihoods for a growing number of people in developing countries around the world. With little or no investment capital or technical knowledge, miners are in great need of resources to help them minimize these impacts. Where alternate economic strategies are viable, these must also be pursued. Worldwide awareness of health and environmental problems and the growing number of children involved in ASM, combined with the reality that mercury contamination crosses national boundaries, has led to much needed international collaboration. Simple technological solutions now exist that can reduce mercury exposure while promoting more cost-effective operations. However, there are several major challenges to their implementation; chief amongst these is that controlling mercury emissions requires addressing the driving forces and pressures that have been barriers – including poverty and disease. Linking experts from different disciplines to create common frameworks for hazard reduction is clearly needed. Especially as the artisanal mining sector in developing countries has seen few examples of long-term community-based efforts combining biomedical, technical, sociological, economic and cultural aspects, new and positive examples are greatly needed.

Another challenge is that governments where ASM is widespread have limited resources, and top-down initiatives based on regulatory approaches are limited, especially due to widespread illegal mercury markets and mining activities. Bottom-up initiatives based on participation and cooperation between miners, government and nongovernmental agencies offer greater promise for community impact. Recognizing the need for synergy between policymaking and practice, the GMP is encouraging the involvement of local inspectors in training workshops along with leaders of mining groups. The effectiveness of the various interventions need to be carefully monitored. Training needs to be broadened to address communities that have hitherto not been reached, and in this respect, a train-the-trainer effect is greatly needed. Through the Global Mercury Project, the United Nations has opened up numerous collaborative opportunities, embracing a model that combines environmental protection with livelihood development to address these challenges. Alliances with new donors and partners, including the private sector, could further reinforce these global efforts in the future.

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Mercury as a Global Pollutant & Fetus as a High-Risk Group to Methylmercury

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Abstract

Mercury is a metal that has long been used because of its many advantages from the physical and chemical points of view. However, mercury is very toxic to many life forms, including humans, and mercury poisoning has repeatedly been established. The main chemical forms of mercury are elemental mercury (Hg^0), divalent mercury (Hg^{2+}) and methylmercury (MeHg; CH_3-Hg^+), and the toxicities and metabolisms of which differ from each other. MeHg is converted from divalent mercury and is a well-known neurotoxicant, having been identified as the cause of Minamata disease. It bioaccumulates in the environment and is biomagnified in the food web. Human exposure to MeHg is mainly through fish and seafood consumption. MeHg easily penetrates the blood-brain and blood-placenta barriers. Therefore, it causes damage to the central nervous system, particularly in fetus. In this paper, we summarize the global mercury cycle and mercury metabolism, toxicity and exposure evaluation, and the thresholds for the onset of symptoms after exposure to different chemical forms of mercury, particularly MeHg.

Key words: mercury, methylmercury, global cycle, metabolism, toxicity, fetus

Introduction

The epidemic called "Minamata disease" is well known as the first instance on record of severe MeHg poisoning caused by man-made environmental pollution, which occurred mainly among fishermen and their families in and around Minamata City. It originated from the consumption of large amounts of fish and shellfish contaminated with MeHg discharged from a chemical plant (Irukayama and Kondo 1966). The principal symptoms were neurological disorders (Takeuchi et al. 1962). The first patient was reported in 1953, and the number of patients rapidly increased after 1955. Up to the present, more than 2000 people have been certified to have Minamata disease. Furthermore, many fetus exposed to MeHg through the placenta of the exposed mother showed severe cerebral palsy-like symptoms, while their mothers had mild or no manifestation of the poisoning (Harada 1978). Outbreaks of the typical fetal-type Minamata disease occurred during 1955-59 when the mercury pollution appears to have been most severe, judging from the incidence of patients (Harada 1978) and the MeHg concentration in the umbilical cords of inhabitants of the area (Nishigaki and Harada 1975). This landmark epidemic was the first to bring worldwide attention to the high risk of fetal exposure to MeHg.

As shown in the epidemic, fetus is a high-risk group for MeHg exposure because of the high susceptibility of the developing brain itself (Choi 1989; Sakamoto et al. 1993; WHO/IPCS 1990). Moreover, MeHg easily crosses the blood-placenta barrier, accumulating more in the fetus than in the mother (Choi 1989; Sakamoto et al. 2004a, 2002; Stern and Smith 2003; WHO/IPCS 1990).

Mercury, one of the most toxic heavy metals, is released into the environment from natural sources and through human activities. Recent studies indicate that human activity contributes about 50–70% of total emission into the environment. That means the anthropogenic emission constitutes a large part of the global mercury cycle (UNEP 2002). Therefore, the effect of MeHg exposure on pregnant women is an important issue for elucidation, especially in Japanese and some other populations which consume much fish and sea mammals (Grandjean et al. 2005, 1997; Myers et al. 2003, 1995; NRC 2000; WHO/IPCS 1990) as a matter of great concern.

Mercury chemical forms and their dynamics in environment

Fossil fuel combustion and volcanoes emit large amounts Hg^0 and particle bond mercury. Most mercury in the air is gaseous Hg^0 because of its much longer retention time in the atmosphere compared with other mercury forms (UNEP 2002). Natural mercury emission at an annual rate of about 1,000 tonnes has continued for millions of years as a result of crustal movement creating volcanic activity. In addition, annually about 2,600 tonnes of mercury, more than twofold the amount of natural emissions, originates from anthropogenic sources, and more than 60% of them results from fossil fuel combustion (UNEP 2002). The estimated amount of anthropogenic mercury emissions in China is particularly high, followed by that in the USA (Table 1). The mercury concentration in the atmosphere of those regions is higher than those in other regions. Also, the mercury concentration in

Table 1. Estimated global atmospheric emissions (metric tons/year)

Continent	Fossil fuel combustion	Non.ferrous metal production	Pig iron and steel production	Cement production	Waste disposal	Artisa-nal gold mining	Sum
Europe	189	15	10	26	12		250
Africa	197	7.9	0.5	5.2			210
Asia	860	87	12	82	33		1070
North America	105	25	4.6	13	66		210
South America	27	25	1.4	5.5			60
Australia and Oceania	100	4.4	0.3	0.8	0.1		100
Summ	1470	170	30	130	110	300	1900+ 300

Source: UNEP, 2002

the atmosphere of the northern hemisphere is twofold higher than that of the southern hemisphere (UNEP 2002). These indicate that global mercury emission has increased since the industrial revolution started. UNEP Global Mercury Assessment project was undertaken to investigate the possibility of setting international limit of mercury emission, deemed necessary because mercury concentration in superficial ice in the Arctic has increased (UNEP 2002). Elemental mercury emitted into the atmosphere is oxidized and transformed into Hg^{2+}, a portion of which is methylated and enters the aquatic food chain. Species higher on the food chain tend to have higher concentrations of mercury, e.g. often above 10 μg/g in whales (toothed whale) and above 1 μg/g in sharks, pike, swordfish and tuna. Although regional pollution caused by a high concentration of MeHg such as in the aforementioned Japanese cases is not presently apparent, the mercury concentrations in fish and other seafood are possibly increasing because of mercury emissions of anthropogenic origin (UNEP 2002). Recently, research focusing on the global mercury cycle has been actively undertaken, particularly in Western countries, because of emissions of Hg^0 and sulphur that polluted the Great Lakes in the USA and the lakes in Scandinavia. These have caused concern regarding a possible increase in human exposure to MeHg in the future.

Metabolism and toxicity of chemical forms of mercury

Human absorption of liquid Hg^0 is low, and acute toxicity does not occur even if the liquid mercury used in thermometers is accidentally ingested. The problem is gaseous Hg^0 resulting from the heating of the mercury, which causes acute interstitial pneumonia when inhaled at a high concentration. About 80% of inhaled gaseous Hg^0 is absorbed into the blood and easily passes through the blood-brain barrier in its unoxidized form, thereby reaching the brain and damaging the central nervous system. With time, gaseous Hg^0 in the body is oxidized to Hg^{2+}, which accumulates in the kidneys and causes kidney toxicity (WHO/IPCS 1991). The absorption of Hg^{2+} in the digestive tract is comparably low. However, a large intake of Hg^{2+}, such as in accidental or suicidal ingestion, causes digestive tract and kidney disorders resulting in death (WHO/IPCS 1991). MeHg is readily absorbed by the digestive tract and enters the central nervous system after passing the blood-brain barrier, thereby causing degeneration and dysfunction of nerve cells (WHO/IPCS 1991; NRC 2000; Minamata Disease Research Group 1968). The symptoms of Minamata disease include sensory disorders of the four extremities, cerebellar ataxia, constriction in the visual field, smell and hearing impairments and disequilibrium syndrome (Minamata Disease Research Group 1968).

Most mercury in fish and other seafood exists as MeHg (more than 90%). Generally, fish and other seafood products are the main sources associated with MeHg exposure in humans; note that whales and tuna, which are at the top of the aquatic food chain, accumulate high concentrations of MeHg (NRC 2000; WHO/IPCS 1976). MeHg transport into tissues appears to be mediated by the formation of a MeHg-cysteine conjugate, which is transported into cells via a neutral amino acid carrier protein (NRC 2000; WHO/IPCS 1976). The brain of the developing fetus is very sensitive to MeHg. In addition, the MeHg concentration in the blood of the fetus is about 1.5-2-fold higher than that of the mother because of the active transport of MeHg to the fetus through the placenta (NRC 2000; WHO/IPCS 1976). Figure 1 shows the relationship between maternal and fetal mercury concentrations in the red blood cells of 63 mother-fetus pairs (Sakamoto et al: 2004a). Therefore, fetus are recognized to be a higest-risk group for MeHg because the susceptibility itself is high and high MeHg accumulates in fetus than mothers.

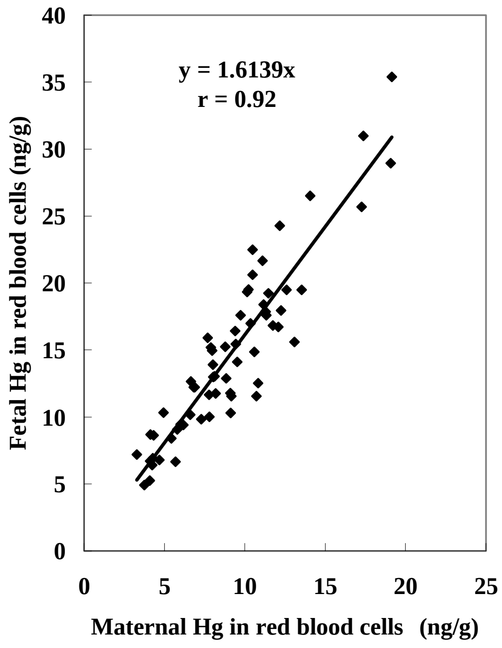

Figure 1. Correlation between maternal and fetal mercury concentrations in red blood cells in 63 maternal-fetal pairs

Exposure assessment in adults

To determine the effect of MeHg on the human body, it is preferred to use a biomarker in the body that reflects the MeHg concentration in the brain, because the major target organ is the brain. In humans, MeHg has on average a biological half-life of about 70 days (whole body) (WHO/IPCS 1976). Generally, its internal retention quantity becomes stable under constant MeHg exposure, which depends on dietary intake. Animal experiments indicate that the ratio of the mercury concentration in the blood to that in the brain becomes fixed at steady state conditions. Therefore, the mercury concentration in the blood is a good biomarker of the mercury concentration in the brain (WHO/IPCS 1990). The mercury concentration in the hair also reflects the MeHg concentration in the blood during hair formation and is frequently used as a biomarker for evaluating MeHg exposure (WHO/IPCS 1990). Generally, the mercury concentration in the hair is 250-300-fold higher than that in the blood, because sulphur-containing proteins in the hair bind to mercury.

The major form of mercury in the urine is inorganic mercury. The mercury concentration in the urine increases with increased amounts of inorganic mercury accumulated in the kidney. Moreover, with exposure to elemental, oxidized and inorganic mercury forms, the total mercury concentration in the urine, which reflects the amount of divalent mercury accumulated in the kidney, is a good biomarker for evaluating mercury exposure. On the other hand, in the case of high-level exposure to gaseous elemental mercury, mercury causes acute toxicity conditions, e.g. respiratory distress, difficult breathing, bronchitis, and renal tubule damage (Japan Public Health Association 2001). Therefore, the lungs are another target organ of acute exposure.

Medical professionals should refer to sampling methods for each chemical form of mercury and its preservation conditions, e.g., these presented by the Japan Public Health Association (Japan Public Health Association 2001), and to the total mercury analysis method in the Manual for Mercury Analysis published by the Japanese Ministry of the Environment (Japanese Ministry of the Environment 2004) for proper sampling and the evaluation of mercury exposure.

Correlations between mercury concentrations in biomarkers of fetal exposure to MeHg at parturition

The National Research Council (NRC 2000) recommended cord blood Hg as the best biomarker for fetal exposure to MeHg. In addition, cord tissue Hg concentration was revealed to be useful as a predictor of the effect of fetal exposure to MeHg (Grandjean et al. 2005). MeHg concentration in preserved umbilical cord was also used as a biomarker for the exposure to fetal-type of Minamata disease patients (Akagi et al. 1998; Nishigaki and Harada 1975).

As shown in Table 2, significant correlations of total mercury and MeHg concentrations were observed among the biomarkers. Total mercury and MeHg in cord tissue showed strong correlations with those in maternal and cord bloods (Sakamoto et al. 2006). The cord blood total mercury is recommended as the best biomarker for fetal exposure to MeHg by the National Research Council (NRC 2000). The strong correlation coefficient between total mercury and MeHg in cord tissue and the high MeHg percentage (about 90%) also suggests that cord tissue MeHg as well as total mercury concentrations are useful as biomarkers for prenatal MeHg exposure. Thanks to the traditional Japanese custom of preserving umbilical cord tissue at parturition. We may use this dried cord tissue to estimate past MeHg exposure.

However, the correlations of total Hg in maternal hair and either total Hg or MeHg in other biomarkers were comparatively low. This may have been due to the fact that we used whole length of hair for Hg analysis in the present study, while Hg levels in newly formed hair reflect those in blood (Phelps et al. 1980). The Hg concentrations in whole hair do not exactly reflect the Hg level in blood at parturition. In addition, another reason lower correlation would be decrease in Hg level by artificial hair waving (Dakeishi et al. 2005; Yamamoto and Suzuki 1978).

Table 2. Correlation coefficients of total Hg and MeHg among biomarkers at parturition

r	Cord-THg	Cord-MeHg	Hair-THg	Maternal blood-THg	Maternal blood-MeHg	Cord blood-THg	Cord blood-MeHg
Cord-THg	1.000						
Cord-MeHg	0.975	1.000					
Hair-THg	0.641	0.626	1.000				
Maternal blood-THg	0.809	0.799	0.648	1.000			
Maternal blood-MeHg	0.846	0.839	0.654	0.981	1.000		
Cord blood-THg	0.848	0.815	0.651	0.888	0.885	1.000	
Cord blood-MeHg	0.873	0.839	0.646	0.882	0.888	0.992	1.000

Normal mercury concentrations of different human biomarkers

The relative concentrations of organism tissues at steady-state exposure are as follows: hair, 250; red blood cells, 2; blood plasma, 0.2, when the relative value of MeHg in total blood is assigned 1 (Sakamoto et al. 2004b). The total mercury concentration in the hair, the biomarker used for the general populace of Japan, is generally within 1-5 μg/g, and rarely exceeds 10 μg/g; that in the blood is generally less than 50 ng/g (Japan Public Health Association 2001; Japanese Ministry of the Environment 2004). However, even if the total mercury concentration exceeds these values, it does not mean that the symptoms of poisoning develop immediately. The total mercury concentration in the hair differs depending on sex and age as a function of quantity and mercury content of fish and seafood consumed. The total mercury concentration Urine is generally less than 10 ng/ml among Japanese. The total mercury concentration in the umbilical cord is generally about 0.1 μg/g (dry weight) (Sakamoto 2006; Akagi et al. 1998), but reached 1-3 μg/g (dry weight) in the residents of Minamata City during the Minamata epidemic (Akagi et al. 1998).

Hair mercury levels in Japan and some Asian countries

The survey of hair mercury levels in Japan had been conducted, focusing on identifying mercury exposure level of general populations without any particular exposure to mercury (Yasutake et al. 2004). The geometric mean of mercury levels were 2.42 μg/g for males (n=4274) and 1.37 μg/g for females (n = 4391). The geometric mean mercury levels among the districts varied from 1.67 to 4.75 μg/g for males and from 1.07 to 2.29 μg/g for females. The values were highest in Chiba (4.75 μg/g for males, n=253; 2.29 μg/g for females n=232). The regional variation seemed to depend on the total amount of daily fish/shellfish consumption and on the preference for tuna consumption.

The average concentration of hair mercury sampled in general populations without any particular exposure to mercury were summarized in Figure 2. (Sakamoto et al. 2005). Such wide regional variations seemed to depend mainly on the total daily intake of fish/shellfish and species of fish/shellfish consumed daily. The inhabitants living in Lake Murray (in Papua New Guinea) area who showed the highest hair mercury level consumed about 9 kg fish /moth (Kyle et al. 1982). The Zhoushan Islands (China) which showed the second highest hair mercury level are famous for the largest fish catches in China. The inhabitants eat fish/shellfish almost every day. The average hair mercury level was the highest level in Japan. The male inhabitants in Hong Kong also showed a level similar to that of Chiba males. The inhabitants in Sihanoukville (Cambodia) similar to that in Chiba, which showed and Davao (Philippines) showed a level similar to that of Japanese males. The town faces the sea, and so fish is a dietary staple. On the other hand, the inhabitants of Sheng Yang (China), Gui Yang (China) and Bangladesh who seldom eat fish/shellfish showed less than half the average Japanese hair mercury level. People living in Kojar and Deder Bubu, Kyrgyzstan, which are completely isolated from the sea, do not have many opportunities to eat fish/shellfish, and showed very minimal mercury levels.

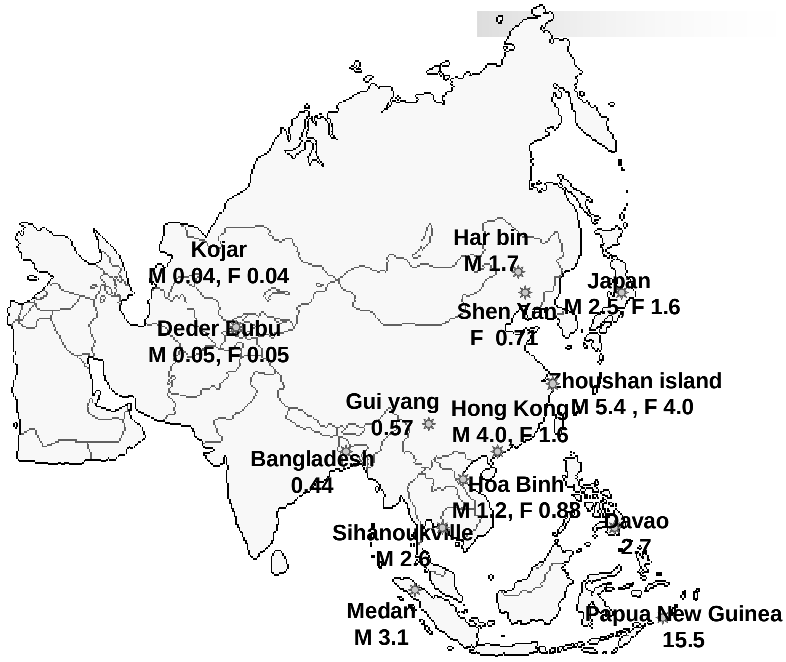

Figure 2. Hair mercury concentrations (μg/g) in some Asia and Oceania districts.

Thresholds for onset of MeHg symptoms in adults

The large-scale poisoning incidents from 1972 to 1973 in Iraq were caused by wheat seed, disinfected with methylmercury. These incidents afflicted more than 6,000 people and resulted in 400 deaths, and the main symptoms shown were similar to these shown in Minamata disease. The study in Iraq showed that the thresholds of mercury body burden at diagnosis of patients were as follows: abnormal sensory, about 25 mg (equivalent to a mercury concentration in blood of 250 μg/l); ataxia, about 50 mg; articulation disorders, about 90; hearing loss, about 180 mg; death, more than about 200 mg. Table 3 show the summary of the thresholds for which the first neurological symptoms appear in adults with the highest susceptibility (WHO/IPCS 1991).

Table 3. Various indices showing thresholds for onset of neurological symptoms in human body (level at which neurological symptoms would appear in the most susceptible adults) (WHO/IPCS. 1990)

Index	Threshold
Average daily intake	3-7 μg/kg
Body burden	15-30 mg（50 kg body
Total mercury in blood	20-50 μg/100 ml
Total mercury in hair	50-125 μg/g

Thresholds for onset of MeHg symptoms during fetal period

Grandjean *et al*. (Grandjean et al 1997) determined the MeHg exposure levels influencing the development of children exposed to MeHg during the fetal period in a cohort study of about 900 residents of the Faroe Islands, where a large quantity of pilot whale meat with elevated mercury content is consumed. The results show a significant association of deteriorated motor function, attention, visual field, speech and language memory with Hg concentrations in cord blood exposure before birth. Myers *et al*. (Myers et al 2003) conducted a cohort study in the Seychelles Islands, where large quantities of fish and other seafood are consumed and the effect of MeHg on children is a source of concern. However, in their study, no results showing a significant association between the biomarkers of MeHg exposure before and after birth were obtained. Kjellström *et al.* conducted a cohort study of New Zealand children (Kjellström T. 1998). In their study, they estimated prenatal MeHg exposure level using maternal hair samples and dietary questionnaires. They observed the adverse effects on children development (Kjellström T. 1998). A similar cohort study is ongoing in Japan (Nakai et al. 2004). The effect of MeHg exposure on fetus remains an important issue to elucidate, particularly in populations that consume high amounts of fish and seafoods. Although the threshold for the onset of symptoms for MeHg is recognized 10-14 µg/g in maternal hair as summarized in Table 4. Tolerable intake levels of MeHg for pregnant women are decided by each country and the authorities concerned, taking safety into consideration. The Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA 2003) established the a provisional tolerable weekly intake (PTWI) for MeHg to 1.6 µg Hg/kg bw/week (equivalent to a hair mercury concentration of about 2.3 µg/g) using uncertain factor 6.4. United States Environmental Protection Agency (USEPA 2001) set the limit to 0.1 µg Hg/kg bw/day (equivalent to a hair mercury concentration of 1.0 µg/g) as reference dose (RfD) using uncertain factor 10. The amount of fish and other seafood consumed by people in Japan and other Asian countries bordering the sea is higher than that consumed by European and American people. The average mercury concentration in the hair of women of childbearing age (15-49 years) in Japan is 1.4 µg/g (Yasutake et al. 2004). In June, 2003, the Japanese Ministry of Health, Labour and Welfare issued standards for the tolerable intake of tooth whales, red snapper, swordfish, bluefin tuna and other fish for pregnant women, owing to the fact that a certain percentage of fish and other seafood contain high MeHg concentrations as a result of biomagnification. In August 2005, the Food Safety Commission, which was requested by the Japanese Ministry of Health, Labour and Welfare to evaluate tolerable weekly intake, established the MeHg TWI to 2.0 µg Hg/kg bw/week (Food Safety Commission 2005) using uncertain factor 4, corresponding to a hair mercury concentration of about 2.8 µg/g.

Table 4. Adopted thresholds, uncertain factor, and tolerable exposure limit for pregnant women by EPA (2001), JECFA (2003), and Japanese Ministry of Health, Labour and Welfare (JHLW 2005)

	EPA	JECFA	JHLW
Total mercury in hair	**10 μg/g**	**14 μg/g**	**12 μg/g**
Uncertain factor	**10**	**6.4**	**4**
Exposure limit	**0.1 μg/kg/day**	**1.6 μg/kg/week**	**2 μg/kg/week**

Summary

In the natural course of events, most human exposure to MeHg is through fish/shellfish consumption. The MeHg exposure levels depend on the amount and species of fish/shellfish consumed daily. The developing brain in the late gestation period is known to be most vulnerable. Further, more MeHg accumulates in the fetus than in mothers. Therefore, efforts must be made to protect the fetus from the risk of MeHg, especially in populations which consume a lot of fish/shellfish.

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Mercury, Fish Consumption and Human Health, with Emphasis on South China

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Environmental Status of South China and sources of Hg

The Pearl River Delta (PRD) in South China is one of the regions in China that has undergone high industrialization and urbanization without due regard for environmental protection, in the past two decades. As a consequence, serious environmental problems included the following (a) Air: Power plants, cement plants, factories and vehicles are the major sources of air pollutants. The high demand of electric power due to export activities has given rise to the increase use of coal, which aggravated the acid rain problem, in addition to the emission of Hg. (b) Solid waste/land: Huge amounts of wastes have been generated, without efficient waste management, resulted in severe land contamination and dereliction. (c) Water: Only 16% sewage is treated in Guangdong Province, compared with other provinces, e.g., 62% in Shanghai and 42% in Jiangsu [1].

Asia has become the largest contributor of anthropogenic atmospheric Hg, responsible for over half of the global emission [2]. This is especially true for China where metal smelting and coal combustion are the two major sources of Hg emission [3]. In the next few decades, a significant increase in anthropogenic Hg emissions is likely owing to rapid economic and industrial development, unless drastic measures are taken.

Bioaccumulation and biomagnifications of Hg

Excessive releases of Hg over time may lead to bioaccumulation and biomagnifications of Hg in the food chains. Our previous study indicated that accumulation of Hg in fish was related to the spatial difference of Hg in sediment. Within the same fish ponds, cultivating different species of fish (polyculture of fish - the traditional freshwater fish culture in the region, with waste materials as the major energy input), the top carnivore *Micropterus salmoides* (black bass) contained the highest levels of Hg (0.0567 mg/kg dw), compared with other species (omnivores, herbivores and filter feeders), a clear indication of bioaccumulation and biomagnifications in the local aquatic food chain [4]. Most of the Hg contained in fish is the highly absorbable methyl form, and percentage of methyl mercury (MeHg) to total Hg is 72-100% in fish [5]. In general, the Hg concentrations in most fish samples in China were lower than the international marketing limit of 0.5 mg/kg, but some marketable and economic fish collected in southwestern Taiwan, Shanxi, Zhejing and Hebie were contaminated with Hg concentrations in excess of 1 mg/kg [3].

Potential health hazards of consuming fish contaminated with Hg

Humans are exposed to both organic (e.g., MeHg) and inorganic Hg. MeHg exposure is mostly dietary and originates from certain types of freshwater fish and seafood [6], giving rise to a serious concern over food safety and human health. Blood [7] and hair [8] are commonly used to assess human exposure to organic and inorganic Hg, but hair is more useful in assessing long term exposure to toxic metals [9, 10]. It has been indicated that individuals consuming 4 or more meals of fish per week had a hair Hg of 4.07 mg/kg dw while those consuming fish less frequently had significantly lower levels (2.56 mg/kg), and men with high hair levels were twice as likely to be subfertile, when compared with men with low levels [11, 12]. Secondary school students in Hong Kong have been advised not to consume excessive amount of predatory fish (such as tuna) which may contain higher Hg, as well as shellfish as they tend to contain higher As and Cd concentrations [13]. It has been proved that both blood and hair Hg levels of children (n=137, mean age=7.2 years) in Hong Kong was elevated and correlated with the frequency of fish consumption. After reducing fish consumption, 5 children and 12 family members who originally possessed toxic Hg levels in their blood and hair had their levels dropped significantly [14].

Many environmental contaminants including heavy metals are immunological disruptors, and the consumption of contaminated fish and seafood is the major source of human exposure to heavy metals such as Hg and Pb [15]. There is substantial evidence showing that allergic disorders are mediated by oxidative stress and associated with Th-2 cytokine production [16, 17]. For patients with chronic recurrent allergies or medication-resistance, overexposure to heavy metals and concomitant oxidative stress may pay a role in the pathogenesis. In addition to severe skin disorders (such as eczema), there seemed to be an increasing number of cases of children with autism recently linking to their high concentrations of heavy metals, especially Hg, in their body (hair, blood and urine), due to the their high consumption rate of fish, as well as their mothers', especially during the later stage of pregnancy [18].

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NIMF Forum 2006 II: The Current Issue of Mercury Pollution in Asia-Pacific Region

Mercury, Fish Consumption and Human Health, with emphasis on S China

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Content

- Hg in the environment
- Human exposure & monitoring
- Human burden and fish consumption
- Fish contamination
- Potential health hazards
- Aquaculture: chemicals used
- Recommendations

Background

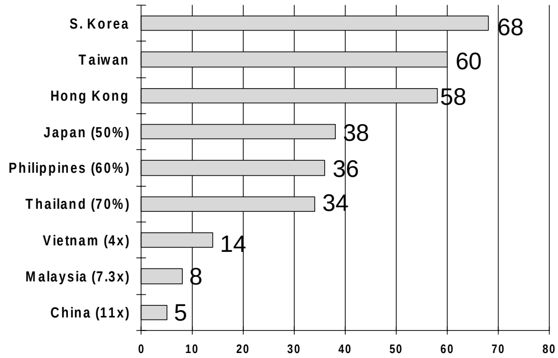
- In China, Hg emission from non-ferrous metals smelting, coal combustion, and miscellaneous activities contributed 45, 38 and 17% to the total Hg emission, with a total amount of 536 (±236) tonnes 1n 1999.
- Recently, the incidence of neurotoxic, allergic, and immune reactive conditions such as autism, have been increasing worldwide.
- USEPA has estimated that most of the cases are related to mercury (Hg) or lead (Pb) toxicity, of which over 25% of children accumulated Hg at dangerous levels.

OCCUPATIONAL SOURCES OF Hg
mostly from Hg vapor release

1. **Hatters (methyl Hg)**
2. **Finger-print police**
3. **Molybdenum refinery**
4. **Fishermen**
5. **Mercury miners**
6. **Pesticide manufacturers**
7. **Hospital employees**
8. **Thermometer workers**
9. **Chlorine manufactures**
10. **Polarography students**

Seafood per capita consumption for 9 Asian countries

(as kg wt per person for 1995)



Consumer Asia, 1997 and Japanese Dept. of Fisheries, 1998.

Freshwater fish species from local markets

Common name	Scientific name	Feeding mode	Food items
Freshwater fish			
Bighead Carp	*Aristichthys nobilis*	Filter feeder	Zooplankton
Catfish	*Clarias fuscus*	Carnivorous	Small fish, insects, crustaceans, plankton, and also rotting flesh and plants
Grass Carp	*Ctenopharyngodon idellus*	Herbivorous	Grass and other submerged higher plants
Grey Mullet	*Mulgil cephalus*	Bottom feeder	Zooplankton, benthic organisms, detritus and plant material
Mandarin Fish	*Siniperca kneri*	Carnivorous	Fingerling and small fish
Mud Carp	*Cirrhina molitorella*	Bottom feeder	Algae, phytoplankton and organic detritus.
Rice Field Eel	*Monopterus albus*	Carnivorous	Crustaceans, insects, fish and invertebrates
Snakehead	*Channa asiatiea*	Carnivorous	Crustaceans, insect larvae and fish
Spotted Snakehead	*Channa maculate*	Carnivorous	Crustaceans, large insects, fish and even frogs
Tilapia	*Oreochromis mossambicus*	Omnivorous	Plant tissue, small fish, shrimp, detritus and sediment.

Marine fish species from local markets

Common name	Scientific name	Feeding mode	Food items
Marine fish			
Bartail Flathead	*Platycephalus indicus*	Bottom feeder	Small fish
Bigeye	*Priacanthus macracanthus*	Carnivorous	Crustaceans, small fish and small invertebrates
Bleeker's Grouper	*Epinephelus bleekeri*	Carnivorous	Fish and crustaceans
Goldspotted rabbitfish	*Siganus punctatus*	Herbivorous	Benthic algae and seagrass
Golden Threadfin Bream	*Nemipterus virgatus*	Carnivorous	Crustaceans, fish and cephalopods
Orange-spotted Grouper	*Epinephelus coioides*	Carnivorous	Fish and crustaceans
Snubnose Pompano	*Trachinotus blochii*	Carnivorous	Sand mollusks and hard-shelled invertebrates
Tongue Sole	*Cynoglossus robustus*	Bottom feeder	Benthic invertebrates
Yellow Croaker	*Pseudosciaena crocea*	Carnivorous	Small fish, shrimps and crabs
Yellow Seafin	*Acanthopagrus latus*	Omnivorous	Benthic invertebrates

Metal concentrations (mg/kg wet wt. ± SD) in freshwater and marine fish from local markets.

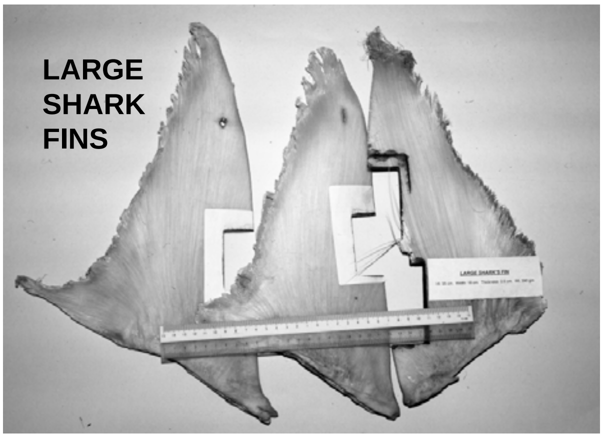
	As	Cd	Pb	Hg
Freshwater fish				
Bighead Carp	0.27e	0.12a	0.33b	0.25bc
Catfish	1.64d	0.11a	0.26bc	0.07d
Grass Carp	0.31e	0.06b	0.14c	0.10d
Grey Mullet	2.13c	0.14a	0.52a	0.09d
Mandarin Fish	0.41e	0.01b	0.11c	0.31b
Mud Carp	0.67de	0.03b	0.18c	0.34b
Rice Field eel	0.77de	0.06b	0.17c	0.15c
Tilapia	0.65e	0.09ab	0.29bc	0.07d
Snakehead	0.24e	0.17a	0.31b	0.08d
Spotted Snakehead	1.80d	0.15a	0.25bc	0.27bc
Marine fish				
Bartail Flathead	2.04	0.09ab	0.12c	0.18c
Bleeker's Grouper	1.59d	0.03b	0.15c	0.37b
Bigeye	1.42d	0.09ab	0.06d	0.14c
Golden Threadfin Bream	5.16b	0.02b	0.21bc	0.32b
Goldspotted Rabbitfish	0.93de	0.05b	0.20bc	0.09d
Orange-spotted Grouper	0.65de	0.05	0.22bc	0.43a
Snubnose Pompano	1.42d	<0.01	0.05d	0.37b
Tongue Sole	8.11a	0.05b	0.06d	0.05d
Yellow Croaker	2.31c	0.05b	0.19c	0.51a
Yellowfin Seafin	2.32c	0.04b	0.24bc	0.36b
Guideline levels				
China[a]	0.5[I]	0.1	0.5	0.3
Hong Kong[b]	2.3[I]	2	6	0.5
US EPA[c]	1.2[I]	4.0		0.4
EU[d]		0.1	0.4	1
Australia & New Zealand[e]	2.0[I]		0.5	1

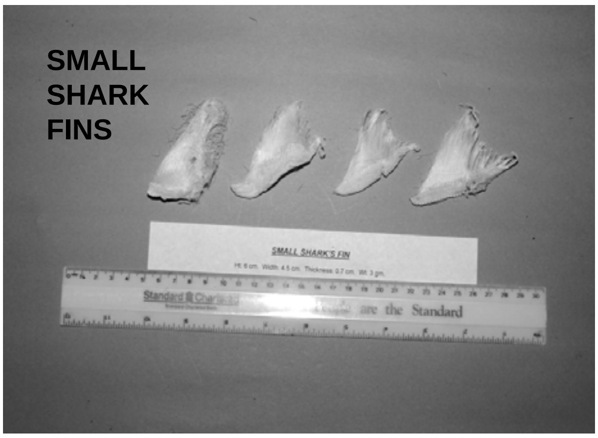
[I]Value for As = inorganic As. Ave conc of inorganic As was estimated by using a value of 10% of total As in accordance with the USFDA (1993). [a]China National Stand Manage Dept (2001); [b]HK Govern (1987); [c]USEPA (2000); Screening values based on consumption of 17.5 g/day of fish for a 70 kg adult; [d]EU (2001); [e]ANZFA (1999).

Daily intakes of metals through fish consumption

	Average concentration (μg/g wet wt.)	EDI (μg/kg body wt./day)	ADI[#] (μg/kg body wt./day)	Ratio of intake to ADI %	RfD[$] (μg/kg body wt./day)	Hazard quotient
Freshwater fish						
As (inorganic)	0.09[*]	0.23	2.15	10.7	0.3	0.07
Cd	0.10	0.25	1	25.5	1	0.25
Pb	0.26	0.66	3.6	18.4		
Hg (Total)	0.17	0.43	0.71	61.0	0.1[@]	4.30
Marine fish						
As (inorganic)	0.26	0.66	2.15	30.8	0.3	0.27
Cd	0.05	0.13	1	12.8	1	0.13
Pb	0.15	0.38	3.6	10.6		
Hg (Total)	0.28	0.71	0.71	100	0.1	7.10

EDI: Estimated daily intake = Aver conc (μg/g) x Consumption (142.4 g/day) ÷ body weight (55.9 kg).
Hazard quotient = EDI/RfD. If ratio less than 1, not obvious risk.
[*] Ave conc of inorganic As was estimated by using a value of 10% of total As (US FDA, 1993).
[#] Calculated from PTWI set by JECFA (1993).
[$] Reference dose of metals established by US EPA (2005).
[@] Methyl Hg accounts for > 95% of total Hg in fish (Bloom, 1992).





Monitoring Human Body Burden

- **Human milk**
  - Chosen as the matrix for biological monitoring by the UNEP Global Monitoring Program for POPs
  - Non-invasive, easy, cost-effective
  - Fairly large volume (30 ml) can be easily collected
  - Disadvantage: only 1 gender of a limited age group can be monitored
- **Blood**
  - Relatively high risk of contact with infectious agents (AIDS, HIV)
  - Lower fat content than human milk, therefore need larger samples
- **Adipose tissue**
  - Tissue usually derived from surgery otherwise difficult to obtain
  - Highly invasive

HEAD HAIR METAL CONTENTS

Aluminum, mercury, nickel, cadmium, antimony, arsenic, beryllium, bismuth, lead, platinum, silver, thallium, thorium, tin & uranium.

- Head hair Hg correlates w/organ Hg, except spleen (Suzuki, 93).
- Good screening test for Pb, Hg, Cd & Al.
- Blood & urine reflect their day-to-day & meal-to-meal fluctuations.
- Half-life (HL) of Hg in blood is 3 days & HL in kidney 64 days.
- Hair Hg is 300x higher than blood Hg (Phelps 80; Airey 83).
- Hair Pb level is 200x higher than in blood (Chattopadhyay 1997).

Hg and Subfertility: the case of Hong Kong

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117 PATIENTS: Subfertile men (age ranges 25-72, with mean 38.1)

Abnormal semen parameters
(WHO Lab Manual. Cambridge University press 1987)

Semen volume < 2 ml
Sperm count < 20 million/ml (Excluding azoospermic men).
Sperm motility < 50%
Normal sperm morphology < 50% (By human observation).

ADDITIONAL DATA ON TEST SUBJECTS

PERSONAL DATA

- Age, Ht, Wt, tobacco consumption (no. of cgt/day),
- hot tub-bath, fish consumption (fish meals/wk),
- mineral water consumption (no bottles/wk),
- no. of amalgam tooth fillings,
- intake of Chinese herbs,
- duration of residence in HK (Yr.),
- district of residence

CLINICAL DATA

- Testicular volume (in ml) & scrotal varices (0,1,2)

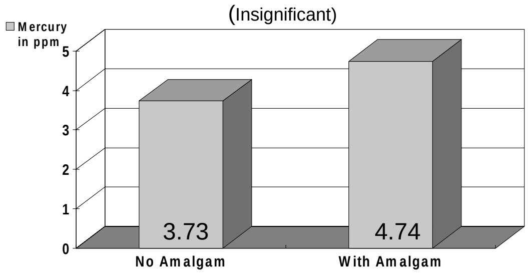
Spermatogenesis a*s a unique*
BIOLOGICAL WINDOW

Spermatogenesis provides a unique biological window that enables us to examine human response at a cellular levels to environmental insults.

TOOTH AMALGAM

Hair Hg Content for Subfertile Male

(Insignificant)



(a=0) n=53 (a=0) n=84

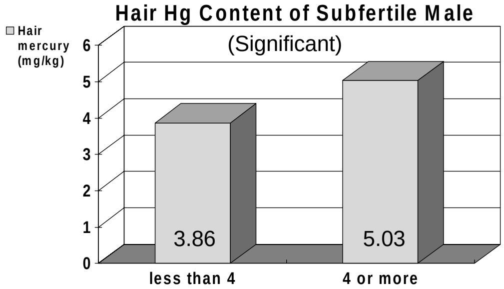
The hair Hg content of Subfertile males with tooth amalgam is higher than those without (27% higher) p=0.082

Composition: 73.61% Mercury 29.39% Silver Density: 13.92

FISH INTAKE

Hair Hg Content of Subfertile Male

(Significant)



Less than 4: n=54 ave. age: 36.6 std 5.6
4 or more: n=61 ave. age: 36.8 std 6.

Hair Hg increased significantly with the increase in fish intake in the subfertile males (30% higher)

Heavy metals (μg/L, fat) in human milk in relation to seafood diet

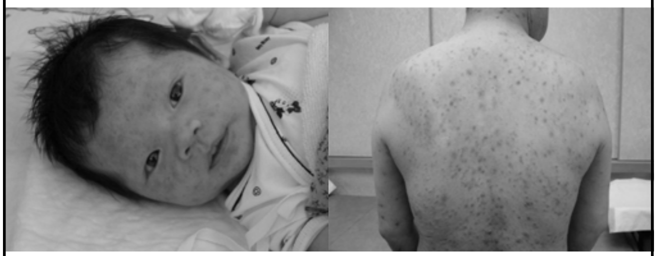
Seafood (times/Wk)	No	As	Cd	Pb	Hg
1--3	7	0.15±0.08 a	0.13±0.11 a	5.16±3.38 a	1.66±0.36 a
4--5	5	0.18±0.10ab	0.19±0.19 a	5.61±2.69 a	0.97±0.23 a
6--7	5	0.33±0.13 b	0.20±0.06 a	9.34±3.16ab	1.34±0.34 a
>7	6	0.31±0.12 b	0.27±0.05 b	11.71±4.17b	1.94±0.45 a

Values followed by the same letter on the same column are not significantly different at the 0.05 probability level according to Duncan's Multiple Range Test

Heavy metals (μg/kg, fat) in visceral adipose tissue in relation to seafood diet

Seafood (times/Wk)	No	As	Cd	Pb	Hg
<=2	7	0.49±0.23a	0.18±0.08a	5.37±2.06a	8.30±2.52 a
3—5	8	0.50±0.09a	0.21±0.05a	4.21±1.66a	10.6±2.41 a
6—8	6	0.44±0.11a	0.23±0.09a	4.61±1.84a	16.0±4.23 b
>8	6	0.48±0.19a	0.32±0.15b	6.95±2.61b	16.5±4.87 b

Values followed by the same letter on the same column are not significantly different at the 0.05 probability level according to Duncan's Multiple Range Test



A 1-month-old infant & a 53-year-old man, both have Hg overload & eczema (Dr Paul Lam, MD)

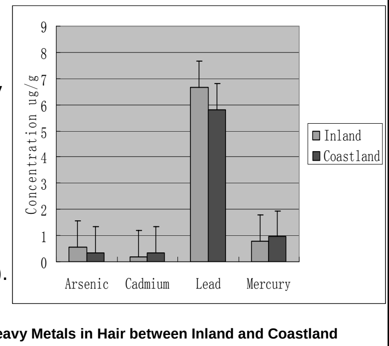
Consumption of contaminated fish

- **Hair** useful in assessing long-term exposure to **toxic metals** (WHO, 1990)
- Individuals consuming 4 or more meals of fish/week had a **hair Hg** (4.07 mg/kg) > those consuming less (2.56)
- Men high **Hg** levels were twice as likely to be **subfertile** (Dickman & Leung 1998)
- Secondary school students are advised **not to consume excessive amount of predatory fish** (such as tuna) **Hg**, & shellfish (**As** & **Cd**) (Food & Environ Hygiene 2002)
- Recommendation of **226 g/week of fish** (high **Hg**) (Kansas Dept of Health & Environ 2006)
- **Average consumption of fish in HK** one of the highest in the world

Comparison of children from coastal areas with inland areas

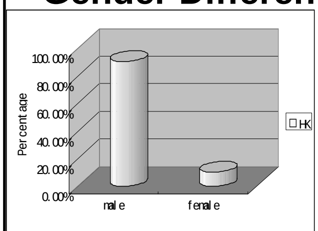
Inland children accumulated more Pb and As (due to heavy polluted environment).

Coastland children accumulated higher Hg and Cd (possibly due to high consumption of seafood).

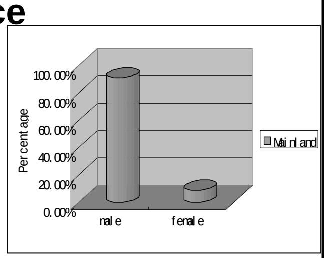


Comparison of 4 Heavy Metals in Hair between Inland and Coastland

Gender Difference



71 autistic children from HK – 64 (90.14%) males, 7 (9.86%) females



111 autistic children from Mainland – 101 (90.99%) males, 10 (9.01%) females

- Young males have weaker antioxidant capacity- greater vulnerability in their brain & nervous systems towards metal toxicity.
- Young females have high levels of antioxidant chemicals – e.g., estrogen is a powerful antioxidant that provides substantial benefits against free-radical mediated damage in aging

Major Findings

- Children are very likely to be more susceptible to a vast number of common pollutants.
- There were significant relationships between heavy metal poisoning and autism.
- Hg is the major metal affected children living around coastal areas, while Pb is the major one affected children from inland areas
- Males were more vulnerable to be affected than females.
  Food Allergy
- Children with autism are more susceptible to allergies and food sensitivities, and this is likely due to their impaired immune system.
- There is growing evidence that many children with autism are sensitive to certain food products.

Two rapidly developing delta regions in China

Impacts of aquacultural activities environmental pollution

- **Industrial & domestic sewage**, together with **nutrient enriched effluent from aquaculture ponds** - **environmental problems in coastal areas**,
- especially, in **coastal bays & estuaries**.

Waste Production in Aquaculture

1. Feed-derived & metabolic wastes

- **Pellets** protein, carbohydrate & fat, additives - vitamins, pigments, etc.
- **By-products of metabolism**
- **Fecal & excretory wastes**
- **Unconsumed feed**
- **Trash fish** is used in HK

2. Inorganic & organic fertilizer

- **Inorganic fertilizer**
- **Organic fertilizer** (animal manure)

- ***Over-fertilization*** may create algal blooms
- ***Pond mud*** can be used as fertilizer for crops – usage declined in recent years

Waste Production in Aquaculture

3. Residues of biocides

- **Natural pesticides**: **tea seed cake, derris powder** & **nicotine**
- **POPs pesticides**: **DDT, endrin, aldrin**
- **Plastic additives**: **flame retardants (PBDE)**
- **Antifoulant:** such as **tributyl tin (TBT)**

4. Therapeutical chemicals & hormones

- **Acetic acid** & **sodium chloride**
- **Malachite green** & **formalin**
- **Antibiotics** - **oxytetracycline** in SE Asia
- shrimp pond – resistant stains of pathogenic vibrios, caused major problems in treatment of vibrio infections
- **Steroids** & **hormones**

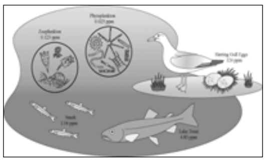
Ecosystem degradation

- **Excessive nutrient loadings** (N & P) could lead to highly undesirable changes in **ecosystem structure & function** -influence phytoplankton growth & contributes to eutrophication;
- Could influence **benthic community**;
- Degradation induced by **invasive exotic species**, leading to local species extinction;
- Escape of aquaculture stocks could result in "**biological pollution**" of wild populations (Paez-Osuna, 2001);
- **Disease outbreaks** & subsequent spread.

Contamination of aquacultural products

- **Persistent toxic substances** leached into watercourses & international waters - also affect aquatic resources
- **Pathogenic organisms**, **endocrine-disrupting compounds, & pharmaceuticals** persisting in agricultural soils fertilized with manure – surface & groundwater – enter into fish ponds

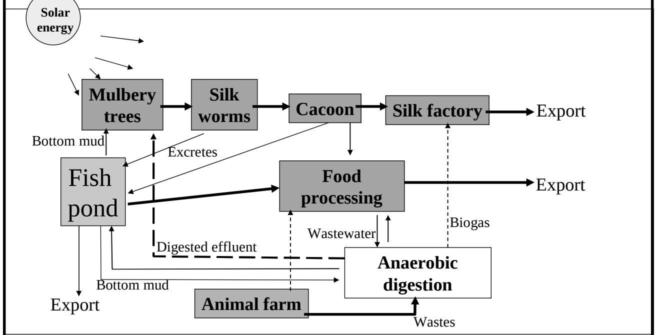
▪**Bioaccumulation** of these toxic substances in aquatic food chains - affect **human health**



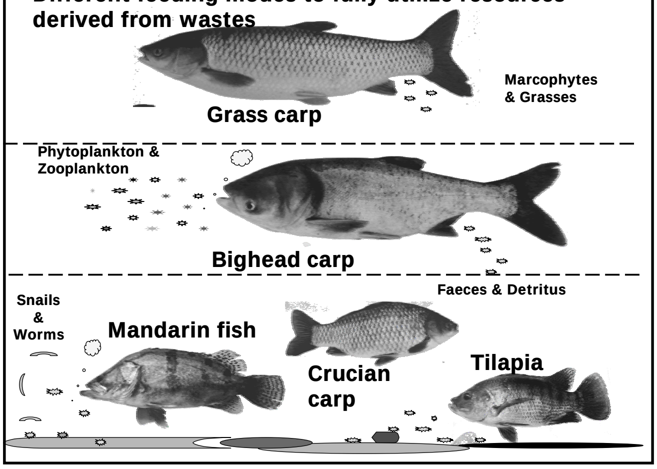
Dyke-pond System:

Polyculture of fish with waste as a major energy input
Recent change: cultivation of high-priced fish under intensive culture, & pollution problem due to rapid development in the region

Mulbury-silkworm-fish-animal system



Different feeding modes to fully utilize resources derived from wastes



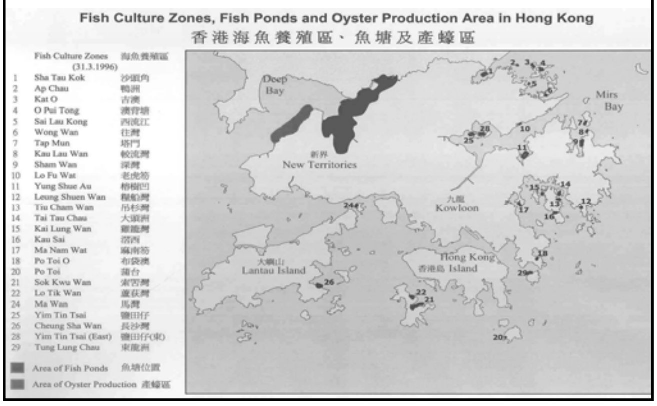
Marine Fish Culture

Typical marine fish culture activity involves rearing of marine fish from fry or fingerlings to marketable size in cages suspended by floating rafts.

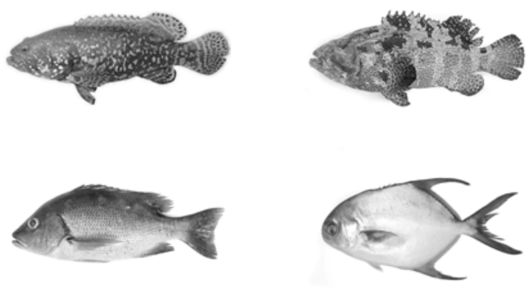
Fry are mostly imported from the Mainland, Taiwan, Thailand, Philippines or Indonesia.

Usually located in sheltered coastal areas.

Marine fish culture activities are located in dedicated sites where hydrography allows.



Common Marine Fish Species



Fish Feed

Trash fish - contributes a significant amount of P, N & C into the environment, through feed wastage, also danger of contamination.

Fish pellets - moist or dry pellet feed would reduce pollution caused & improve both the feed efficiency as well as fish health.

Effects of heavy metals & POPs on fish

- **Trophic position of fish** determines uptake of contaminants, with carnivorous fish accumulating more than herbivores
- **Fish have ability to regulate heavy metal content** (except for Hg), & tend to accumulate metals in parts other than muscle
- **Bioaccumulation & biomagnfication** through food chain (e.g. Hg, DDT)

Problems of current management scheme on aqucaulture

- Lack of coordination among users;
- Scarcity of baseline information;
- Overlapping jurisdiction and inter-agencies conflicts;
- Deficiency in scientifically sound planning and zonation scheme;
- Insufficient local intelligence;
- Poor financial sources;
- Lack of public involvement.

Importance of Aquaculture

- In the 3rd Millennium aquaculture is forecast to contribute to **global security** even more than in the past 3 decades (FAO, Dec 2001)
- A large portion of global production comes from **small-scale producers in developing countries**
- **Sustainable use of aquatic resources** can be achieved through vigorous & **combined efforts by all sectors**: farmer cooperatives & agencies, regulators, policy markers & planners, scientists, NGOs & other aquatic resource users

Recommendations

- **Development of permits** (size & location of the farm, EIA)
- **Environmental quality standards** (nutrient loading limits, discharge), **waste minimization regulations** (feeding management)
- **Development of best management practices, integrated coastal management (ICM)** -as a sustainable approach (including aquacultural activities)
- Setting **regulations on the use of chemicals in aquaculture**
- Setting **guidance values** of heavy metals & POPs in foods, to safeguard environ & human health, & to meet food safety standards for exports
- **Regular monitoring of heavy metals & POPs** in different ecological compartments & human body burden, in order to protect at risk populations, and also to comply with the Stockholm Convention on POPs

Acknowledgements:

Group Research, Central Allocation, Research Grants Council of HK, Environmental & Conservation Fund, Hong Kong, and also Strategic Research Fund, Science Faculty, HKBU

•THANK YOU

Stockholm Convention POPs : The Dirty Dozen

Pesticides	Industrial Chemicals	Unintended By-products
Aldrin	PCBs	Dioxins
Chlordane	Hexachlorobenzene	Furans
DDT		
Dieldrin		
Endrin		
Heptachlor		
Hexachlorobenzene		
Mirex		
Toxaphene		

The New POPs

Pesticides
- Chlordecone
- Lindane & hexachlorocyclohexanes

Flame retardant
- Pentabromodiphenyl ether
- Hexabromobiphenyl

Perfluorooctane sulfonate (PFOS)

Effects of POPs

Adverse health, ecological and environmental effects:

- Carcinogenicity
- Reproductive impairment
- Developmental & immune system changes
- Endocrine disruption
- Threat of lowered reproductive success
- Loss of biological diversity

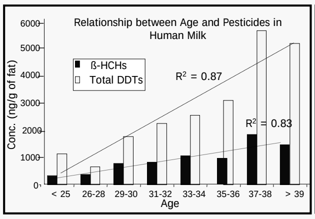
Potential health risk due to consumption of contaminated fish:

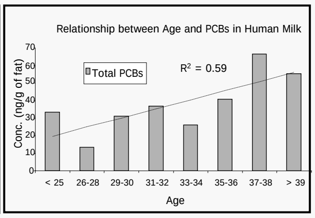
DDTs (ng g^{-1} wet wt) in fish from the Pearl River Delta

	Tanzhou	Sanjiao	Guang-zhoushi	Shipai	Changan	Maipo
Bighead	25.3 (a)	1.5 (c)	2.3 (c)	7.7 (b)	3.3 (c)	7.4 (b)
Grass carp	13.1 (b)	8.0 (d)	20.6 (a)	9.3 (cd)	7.4 (d)	11.2 (bc)
Crucian	5.1 (c)	4.2 (c)	28.5 (a)	17.6 (b)	9.8 (c)	_ _
Tilapia	_ _	3.7 (c)	11.7 (b)	29.9 (a)	3.8 (c)	3.1 (c)
Mandarin fish	_ _	38.3 (b)	62.1 (a)	18.2 (c)	_ _	11.2 (c)

 # Tissues contaminant screening guideline $\boxed{\text{(14.4 ng g}^{-1}\text{ wet wt.)}}$ is for carcinogen. Values based on consumption of 142.2 g day^{-1} of fish (3-4 meal per week) for a 70 kg adult (US EPA 2000).

Human Milk in Hong Kong and Guangzhou





- **Study period: June 1999 – July 2000**
- **Hong Kong (n=115), Guangzhou (n=54)**
- **+'ve correlation between age of donors and accumulated levels of pesticides and PCBs**
- **+'ve correlation between fish consumption and pesticide and PCB levels**
- **Comparable levels of POPs between Hong Kong and Guangzhou**
- **p,p'-DDT, p,p'-DDE, ß-HCH concentrations in Hong Kong and Guangzhou milk were 2-15x higher than in UK, Germany, Sweden, Spain, Canada**
  - **PCBs: ~10x lower**
- Lower p,p'-DDE/p,p' DDT ratio in Guangzhou indicates more recent use than Hong Kong

(Wong et al. (2002). Arch Environ. Contam. Toxicol. 43:364-372)

Survey Results of Mercury Exposure and Policy for Mercury Management in Korea

Guen-Bae Kim[1], Dae-Seon Kim[1], Young-Hee Chung[1]

[1]National Institute of Environmental Research , Ministry of the Environment, Korea.

While there was some accidents and damages due to the mercury pollution in many place, no serious problem didn't occur in Korea. For this reason government and people also didn't have any big concerns about mercury pollution. There were not guidelines for environmental media, and any survey and monitoring program had not been done until 2003. Only guidelines for soils and Effluent sources had been existed. But the facts that almost half of worldwide mercury effluent were occurred in Asia and atmospheric mercury from China can be transferred into US were proposed by UNEP, many Korean scientists and NGOs insisted the necessity of appropriate measures and investigations into mercury pollution. According to these requests, government began the examination for the measures to reduce mercury pollution.

Most of investigations have been conducted by NIER(National Institute of Environmental Research) under the control of ministry of environment. According to the results, it was known that mercury used for the industry amounted to about 25ton officially and most of which has been used for manufacturing fluorescent lamp, catalyst, reagents. Although it is known that a large amount of mercury were generated from the coal-fired power plants and incineration facilities, only it is estimated that the amount of mercury effluent from the combustion might be 8.3 ton. The survey for incineration facilities is now going on by NIER. The environmental monitoring and survey on exposure to mercury were implemented in 2005. The concentrations of mercury were 0.0069 $\mu g/m^3$ in air, 0.0177- 0.0465 µg/g in soil, none in river water. In the results, the amount of daily mercury intake was about 18.8 µg/day/person, which was mainly attributed to food such as fish in Korean and the blood mercury levels were 4.34ppb in adults, 2.13ppb in children, which didn't reach at the guidelines of German CHBM and U.S EPA. But the important thing is that exposure level were 5 or 8 times higher than that of German and U.S. and the percentage of pregnant women who exceed the EPA guideline in blood mercury was 27% and some people showed over 50ppb in the coastal areas.

Korean government began to prepare measures to reduce the mercury pollution, and finally "Governmental Policy for Mercury pollution management" was established and implemented in June, 2006. In this policy, regulations for the products and waste containing mercury, and enforcement of effluent guideline of coal-fired power plant and incineration facility, introduction of guideline for mercury content in fish, monitoring of pollutant exposure to people in every 2 year were included.

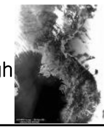
Results of Mercury Exposure Survey and Policy for Mercury Management in Korea

National Institute of Environmental Research
Ministry of Environment, *Korea*
Geun-bae Kim
National Institute for Minamata disease. *Japan*
2006. 11. 28

♦ Environmental Epidemiology Division

Background

- UNEP Global Mercury Assessment (GMA 2002)
  - Mercury is a Global pollutant.
  - Any countries cannot meet their Hg goal by their sole action.
  - Asian Hg emission and atmospheric level are highest in the world
  - High influence of Hg from China on other country's atmosphere
- Increasing concern about Hg pollution and effect in Korea
  - Interest in Hg pollution has been increasing
  - Hg Use and Emission is increasing up to recently
  - Not enough data available about Hg contamination
  - Concern for health due to Hg pollution came to be high



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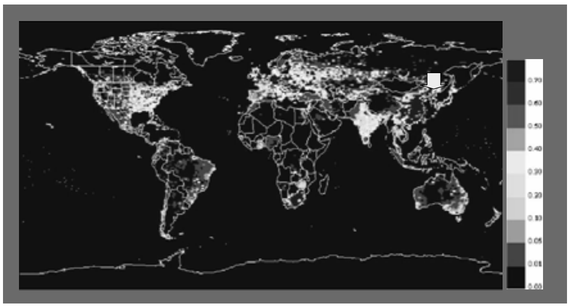
- World Mercury Emission



A.P. Dastoor, Y. Laroque (2004. Atmospheric Environment 38. ton/yr)

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- Estimates of Global anthropogenic Hg Emission

unit : ton/yr

continent	Stationary Combustion	Non-ferrous Metal Production	Iron & Steel Production	Cement Production	Waste Disposal	Mining	계
EU	186	15	10	26	12	–	250
Africa	197	7.9	0.5	5.2	–	–	210
Asia	860	87	12	82	33	–	1070
North America	105	25	4.6	13	66	–	210
South America	27	25	1.4	5.5	–	–	60
Oceania	100	4.4	0.3	0.8	0.1	–	100
Total		170	30	130	110	300	

Source : UNEP(2002)

♦ Environmental Epidemiology Division, NIER.

Survey

- Evaluation of Mercury pollution in Environment
  - Amount of domestic mercury use
  - Emission amount from industrial area
- Human mercury exposure
  - Survey on mercury exposure level of school children
  - Investigation of Hg exposure level of adult
  - Evaluation of Health effect

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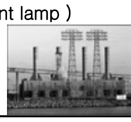
Emission source

- Natural source
  - Natural weathering and mobilization from Earth's crust
  - There is no active volcano in Korea
  - Data have been rare in Korea

- Anthropogenic sources in Korea
  - Coal-fired power and heat production (largest single source)
  - Cement production
  - Metal extraction, processing
  - Manufacturing of product containing Hg (Fluorescent lamp)
  - Incineration
  - above all emissions source exist in Korea



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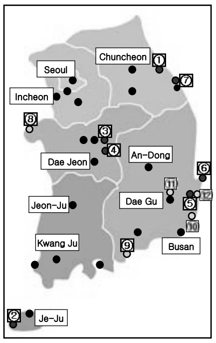
- Locations for Hg Exposure Survey



Survey on Exposure of Children

① Jumunjin (red)
② Go-san
③ Cheong-won
④ Cheong-ju
⑤ Gyeong-ju 1
⑥ Po-hang
⑦ Gang-reung
⑧ Dang-jin (power plant, yellow)
⑨ Ha-dong

Health Effect Survey

⑩ Ulsan (green)
⑪ Dae-gu
⑫ Gyeong- ju 2

Survey on Exposure Adults (above 20 y)

Seoul and 19 area (Black)

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Results

Power Plant in Korea

Sampling

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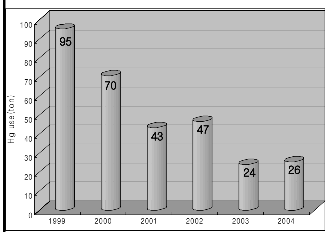
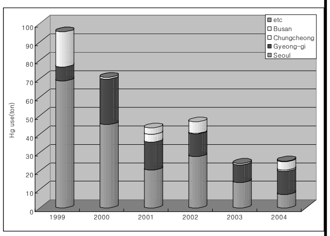
- Trend of Domestic mercury Use in products (ton)



Total Hg Use



Regional Use

* source: Toxic compound use declaration (Ministry or Environment 2005)

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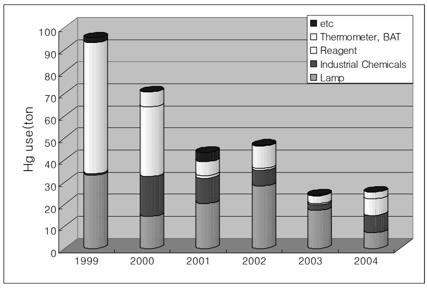
- Areas mercury used in Korea



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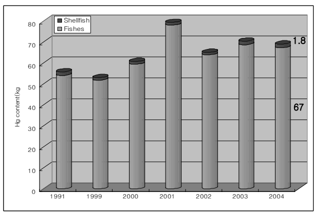
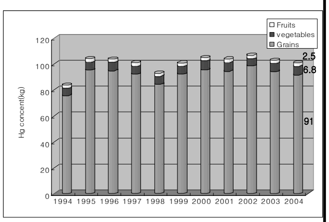
- Estimates of Hg content Marine and Agricultural product (kg)



Marine



Agriculture

* source: amount of agricultural and marine product use (Ministry of Agriculture and Forestry)
amount of marine product use (Ministry of Marine Affair)
Import and export amounts of a & m product (korea customs service)
Hg contents in food and product (KFDA)

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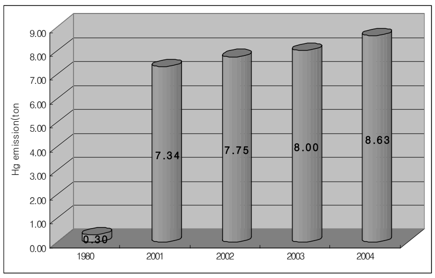
- Estimates of Hg Emission from coal-fired power plant (ton)



- Sources for Estimation: 1. Use amount of coal (Ministry of Commerce and Industry and Energy).
2. Ave. Hg content in coal 0.2㎍/g , Hg emission after combustion: 90% of content (Prestbo 1993).
3. Without considering removal rate of Hg, only amount in theory

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- Summary of Total Exposure Level in Children

Unit: Blood ppb, Urine ㎍/g-Creatinine

		Number of sample	Concentration	*p*-value
Blood	Boy	322	2.19 ±1.44	0.11
	Girl	339	2.06 ±1.28	
	Total	661	2.13 ±1.36	
Urine	Boy	302	2.97 ±2.53	0.16
	Girl	304	3.27 ±2.87	
	Total	606	3.12 ±2.71	

- Hg level in Cord blood

	Sample number	Concentration
Cord blood	22	5.79 ±1.97

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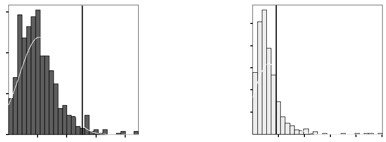
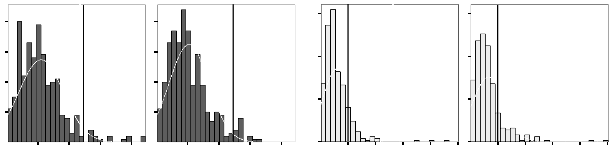
Distribution of Hg Exposure level



- Total distribution exposure of Blood, Urine Mercury



- Sexual difference of Hg exposure distribution in Blood, Urine

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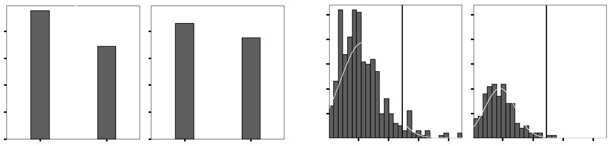
- Blood Hg level according to Preference for fish

Unit : ppb

Blood	Preference for fish				*p*-value
	S no.	like Conc.	S no.	Don't like Conc.	
Boy	223	2.38 ±1.54	82	1.72 ±0.99	0.00
Girl	238	2.14 ±1.36	86	1.87 ±1.04	0.06
Total	461	2.26 ±1.45	168	1.80 ±1.02	0.00



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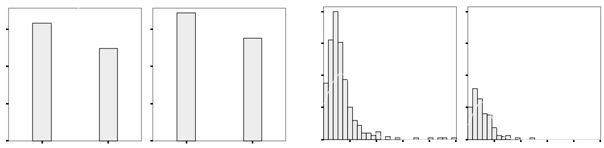
- Urine Hg level according to Preference for fish

Unit: ㎍/g-Creatinine, (-) : % Ratio

Urine	Preference for fish				*p*-value
	S no.	like Conc.	S no.	Don't like Conc.	
Boy	211 (73)	3.16 ±2.79	76 (27)	2.48 ±1.76	0.05
Girl	212 (73)	3.43 ±3.09	79 (27)	2.76 ±2.03	0.08
Total	423 (73)	3.29 ±2.94	155 (27)	2.62 ±1.90	0.01



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- Hg levels according to Intake frequency of fish

Unit: Blood ppb, Urine ㎍/g-Creatinine

		Hg level as Intake Frequency					*P*-value
		NO	≤ 1 / wk	2,3 / wk	4,6 /wk	≥ 1 / day	
		S no.	S no.	S no.	S no.	S no.	
Blood	boy	1.33 ±0.81	2.18 ±1.52	2.19 ±1.24	2.97 ±1.91	2.08 ±1.29	0.00
		23	123	119	33	8	
	girl	1.64 ±0.84	1.93 ±1.09	2.18 ±1.42	2.60 ±1.46	2.27 ±1.48	0.03
		21	135	138	33	4	
	Total	1.48 ±0.83	2.05 ±1.32	2.18 ±1.34	2.78 ±1.70	2.15 ±1.29	0.00
		44	258	257	66	12	
Urine	Boy	2.04 ±0.99	3.15 ±2.89	2.83 ±2.50	3.62 ±2.11	3.27 ±2.48	0.23
		20	118	111	31	8	
	Girl	3.24 ±2.95	3.11 ±2.24	3.40 ±2.95	3.37 ±4.61	2.50 ±0.79	0.92
		21	118	128	27	4	
	Total	2.66 ±2.27	3.13 ±2.58	3.14 ±2.76	3.50 ±3.47	3.01 ±2.06	0.68
		41	236	239	58	12	

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- Regional Difference of Hg level

Unit : Blood ppb, Urine ㎍/g-Creatinine

		Coastal		Inland		*p*-value
		S no.	Conc.	S no.	Conc.	
Blood	Boy	275	2.39 ±1.43	47	1.01 ±0.72	0.00
	Girl	274	2.27 ±1.30	65	1.20 ±0.67	0.00
	Total	549	2.33 ±1.37	112	1.12 ±0.70	0.00
Urine	Boy	261	2.85 ±2.44	41	3.70 ±2.97	0.05
	Girl	245	3.24 ±3.01	49	3.43 ±2.25	0.64
	Total	506	3.04 ±2.53	100	3.54 ±2.56	0.09

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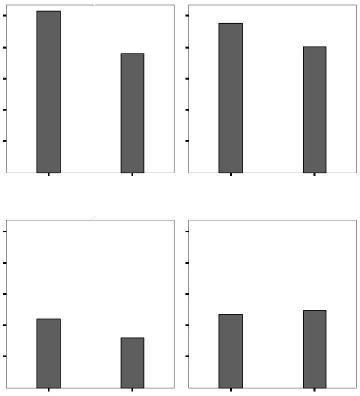
- Comparison of Blood Hg level with Region and Preference for fish

Coastal

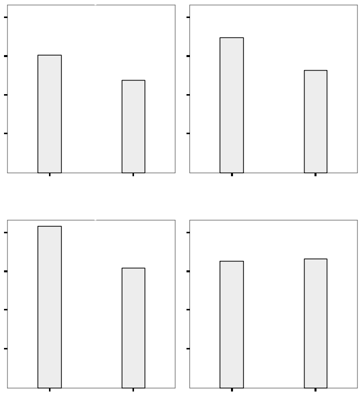
Inland



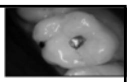
- Comparison of Urine Hg level with Region and Preference for fish

Coastal

Inland

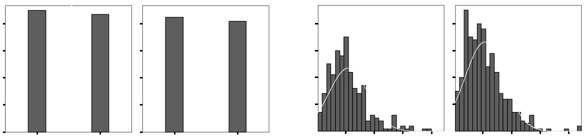


- Blood Hg level according to Dental amalgam experience

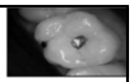


unit: ppb

Blood	Dental amalgam experience				p-value
	S no.	NO Aver. conc.	S no.	Yes Aver. conc.	
Boy	132	2.24 ±1.41	179	2.17 ±1.49	0.00
Girl	132	2.12 ±1.34	194	2.04 ±1.26	0.09
Total	264	2.18 ±1.37	373	2.11 ±1.38	0.50

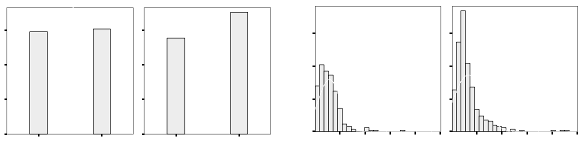


- Urine Hg level according to Dental amalgam experience



unit: µg/g-Creatinine

Urine	Dental amalgam experience				p-value
	S no.	NO Aver. conc.	S no.	Yes Aver. conc.	
Boy	124	2.95 ±2.17	167	3.04 ±2.81	0.78
Girl	118	2.77 ±2.19	175	3.51 ±2.83	0.02
Total	242	2.86 ±2.18	342	3.28 ±2.83	0.05

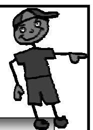


- Hg level with Coal- fired Power-plant is or not.

Unit: Blood ppb, Urine µg/g-Creatinine

		Be		Not		p-value
		S no.	Conc.	S no.	Conc.	
Blood	Boy	58	1.05 ±0.38	264	2.44 ±1.46	0.00
	Girl	69	1.03 ±0.38	270	2.33 ±1.29	0.00
	Total	127	1.04 ±0.38	534	2.39 ±1.38	0.00
Urine	Boy	53	2.74 ±2.89	249	3.01 ±2.45	0.48
	Girl	68	2.62 ±1.83	236	3.46 ±3.09	0.01
	Total	121	2.68 ±2.35	485	3.23 ±2.79	0.04

- Comparison of General Health index measures with Hg level



Items		Measures		
		below average	above average	p-value
Blood Pressure	Systolic	115.9 ±13.0	115.6 ±11.6	0.84
	Diastolic	73.8 ±8.5	74.4 ±8.9	0.53
Lipid	Total cholesterol	168.8 ±28.6	170.7 ±30.6	0.60
Liver	SGOT(AST)	22.8 ±5.4	23.1 ±4.4	0.54
	SGPT(ALT)	11.2 ±6.1	11.6 ±6.9	0.66
	Bilirubin	0.61 ±0.21	0.59 ±0.25	0.45
Kidney	BUN	11.2 ±2.6	11.2 ±2.6	0.89
	Creatinine	0.62 ±0.09	0.60 ±0.08	0.05
	Calcium	9.1 ±0.5	9.1 ±0.4	0.24
Blood	RBC	4.57 ±0.28	4.59 ±0.33	0.66
	WBC	6.84 ±1.87	6.48 ±1.60	0.08
	Platelet	322.2 ±60.4	323.5 ±65.9	0.87

- Comparison of Cognitive and Personal ability test with Hg level

	Items	Results		
		below averag.	above averag.	p-value
Cognitive Ability	Intelligence (IQ)**	107.7 ±16.1	108.1 ±13.0	0.86
	Vocabulary (T)***	53.0 ±10.3	53.5 ±9.0	0.66
	Inference (T)	55.0 ±9.9	55.0 ±8.2	0.97
	Mathematics (T)	52.8 ±10.0	54.3 ±9.6	0.20
	Perception (T)	54.2 ±9.5	52.7 ±9.7	0.21
Personal ability	Egotistics (T)†	49.7 ±10.4	50.2 ±10.6	0.67
	Voca develop (T)	50.5 ±11.5	47.1 ±9.3	0.01
	Position develop(T)	50.0 ±10.8	47.9 ±10.3	0.12
	Family relation (T)	49.5 ±10.1	48.9 ±10.3	0.62
	Social relation (T)	52.3 ±7.4	52.2 ±7.6	0.96

* unit : Mean±SD

** IQ : As National standardization, comparative score of same grade of all students, these group represented mean of 100 standard deviation of 16.

*** T score (cognitive) : In order to generalize mean(50) and standard deviation(10), convert score from distribution of standardization group

† T (personality) : Convert score based on Mean ±SD of standardization group of 4-15 years old.

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- Results Blood Mercury Exposure Survey on Adults in Korea

Unit : Blood conc. ppb

Contents		Geometric average	Results				
			50 th	75 th	90 th	95 th	No. sample
Total		4.25	4.58	6.68	9.20	11.38	1750
Age	20 – 29	3.92	4.24	6.12	8.54	9.35	235
	30 – 39	4.04	4.41	6.54	8.84	10.35	412
	40 – 49	4.74	5.19	7.53	9.86	12.19	422
	50 – 59	4.47	4.83	7.02	9.72	12.50	359
	Above 60	3.96	4.28	6.18	8.91	11.60	322
Sex	Male	4.95	5.35	7.85	10.16	12.26	801
	Female	3.74	4.02	5.95	8.06	9.77	322
Area	City	4.18	4.52	6.62	9.03	10.66	1394
	Rural	4.54	4.72	7.08	10.08	13.88	356

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- The Ratio of people as Recommending Guideline (US EPA)

Unit : Number (% ratio)

Contents		Results		
		Below 5.8㎍/L	Above 5.8㎍/L	No. sample
Total		1,153 (65.85)	597 (34.11)	1,750 (100)
Age	20 – 29	173 (9.89)	62 (3.54)	235 (13.43)
	30 – 39	275 (15.71)	137 (7.83)	412 (23.54)
	40 – 49	246 (14.06)	176 (10.16)	422 (24.11)
	50 – 59	230 (13.14)	129 (7.37)	359 (20.52)
	Above 60	229 (13.09)	93 (5.31)	322 (18.40)
Sex	Male	458 (26.17)	343 (19.60)	801 (45.77)
	Female	695 (39.71)	254 (14.51)	949 (54.23)
Area	City	230 (13.14)	126 (7.20)	356 (20.34)
	Rural	923 (52.73)	471 (26.91)	1394 (79.66)

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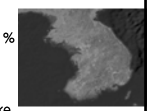
Conclusions of Survey

- Domestic Hg Emission in Korea
  - In product manufacturing, the amount in use is decreasing
  - In coal-fired Power-plant, emission amount is increasing still recently
  - Total amount of Hg emission was less than 32 ton / year.
- Mercury Exposure levels
  - Korean's average exposure levels is under the HBM reference values (Blood: 5 ㎍/L)
    - ⓐ School children
      : Blood conc. 2.13 ㎍/L
      : Ratio of over-the guideline value : blood 4.54 %, urine 13.86 %
    - ⓑ Adults
      : Blood conc. 4.25 ㎍/L
      : Ratio of over-the guideline value : blood 34.11 %
  - There is close correlation between Hg level in blood and fish intake.
  - Blood Hg levels in coastal area are higher than that of inland about 2 times.
  - Dental amalgam experience affects the mercury content in urine.
  - Coal-fired Power plant didn't influence on the Hg levels in blood and urines
    : blood Hg level of people live in where power plant is 50% less than that of pp is not.



- Health Effects of Mercury exposure
  - There are no evidences that Hg exposure affected adversely on children's health

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Policy for Mercury management

Background

- Increasing concern and Results of survey on Mercury
  - Increasing health concern associated with pollutants in Korea
  - Hg Use and Emission is not decreased until recently
  - Higher level of Hg in blood than US(0.82) and Germany(0.58)
  - 27% of women in child-bearing age exceed EPA guideline value
  - In some area, blood mean Hg is amount to 8.1 ㎍/L
- International movement for Hg pollution
  - UNEP urge to establish proper measures to reduce Hg pollution
  - In Global mercury assessment report, Hg is a Global pollutant.
  - Asian Hg level in air and Hg emission are highest in the world.
  - Many scientists insist Influence of Hg from China is serious

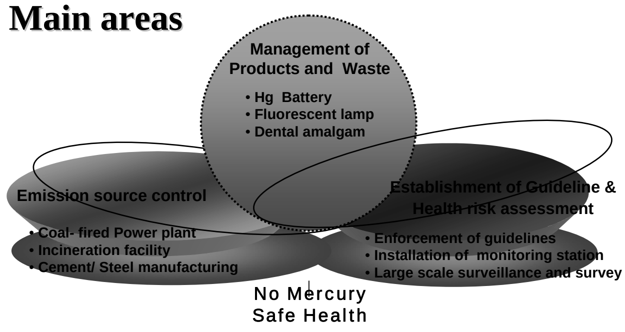
Policy for Mercury management

Purpose

- Provision of legal basis
  - Provision of official basis for management and survey
- Reduction and Control of Hg Pollution
  - Diminish domestic Use and Emission of Hg for ecosystem preservation
- Health protection and International cooperation
  - Government examined the Hg pollution in environmental media
  - Survey on the health status and exposure level
  - To get enough data and service correct information
  - To participate into the international cooperation
  - Protection of people's Health from Hg pollution, finally.

Policy for Mercury management

Main areas



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Policy for Mercury management

Management of Product and Waste

Before

▶ Hazardous toxic material
- Designation in 1999
- only in point source

▶ Battery
- Hg content below 1ppm
- Hg battery can be used

▶ Fluorescent Lamp
- included in EPR list in 2004

▶ Dental amalgam
- No rules

After 2006

▶ Hazardous toxic material
- investigate also in non-point source

▶ Battery
- Hg battery can not be used more

▶ Fluorescent Lamp
- Hg content regulation: below 7 mg/per (EL mark)
- Recommendation for use of EL mark product

▶ Dental amalgam
- designated into special hazardous waste
- Include Resin composite material in insurance list

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Policy for Mercury management

Emission Sources Control

Before

▶ Regulations for Hg Emission
- Coal-fired power plant Incineration, boiler : 5 ㎎/Sm³
- Cement/ Steel manufacturing : No rules

After 2006

▶ Enforcement of Regulations for Hg Emission
- Coal-fired power plant Incineration, boiler : 1 ㎎/Sm³
- Cement/ Steel manufacturing facility : included in regulations facility from 2007

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Policy for Mercury management

Guidelines and Health risk assessment

Before

▶ Monitoring stations
- Water, Soil for Hg (1989)
- Atmosphere : None

▶ Guidelines
- water: ND, soil 4~40㎎/㎏
- atmosphere : None
- Hg in Fish : None

▶ Survey and Monitoring
- Hg Exposure survey : for Children & Adults in 2005

After 2006

▶ Monitoring station
- Installation air monitoring station in 2006

▶ Guidelines
- atmosphere : will be set in 2007
- Hg in Commercial fish predatory fish : 1 ㎎/㎏, the others : 0.5 ㎎/㎏
- Fish consumption advisories : Preparing

▶ Survey and Monitoring
- Health and exposure survey in 13 areas : 1 Control area , 7 industrial complex 5 Closed metal mining region

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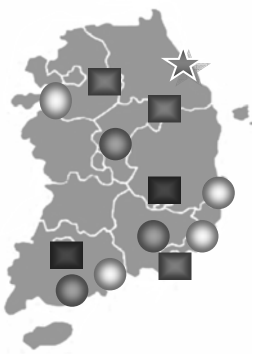
◎ Health Survey Plans in Korea



- National Industrial Complex
  - Undergoing
  - Planning
- Closed Metal Mining Area
  - Undergoing
  - Planning
- Control Area
  - Undergoing

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Thank you.

The Road to Acceptance

A Survey of Environmental Pollution by Mercury Derived from a Chemical Factory Drain in Guizhou, China

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Abstract

Pollution of farmland by irrigation including mercury derived from an acetaldehyde producing process in a chemical factory is the subject of the present work. The field of the study is located in sub-urban of Quingzhen City, Guizhou, China. The factory had been discharging wastewater from 1970 to 2001 into a stream, which is utilized as irrigation for 180 ha of farmland. In the preliminary investigation done in between 1997 to 2000, mercury concentration in the water and fish in the Lake or river as well as hair of residents in the irrigated area was not significant. However, the soil of farmland receiving irrigation as well as the sediment in the irrigation canal suffers high level of mercury. Then, investigation of mercury distribution in the farmland was performed systematically under 100m and 50m meshwork. The highest concentration of total mercury in soil was 271.6 ppm and that of methyl mercury was 199.9 ppb. The distribution of methyl mercury was mainly found at paddy field along the stream in the field from the waste gate to about 3.5 km downstream, where the irrigation canal diverges. About 80 % of the whole amount of mercury deposit is estimated to be included in the vicinity field. Therefore, that field could be the candidate to be remediated.

Quingzhen City locates near Guiyang City, the capitol of Guizhou Province in southern central of the People's Republic of China (Fig. 1). This region is called Yun-Gui Plateau, a hug karst table land spread from Guizhou to Yunnan Province.

Maotiao River runs near Qingzhen City provides water for irrigation, industrial water, electricity generation, fish bleeding as well as the drinking water to the residents around the river including Guiyang City, and finally flow into Chang Jiang near Chongqing. For the purpose of water supply, two lakes are artificially built in this river named Hongfeng Lake in upstream and Baihua Lake in downstream (Fig. 3), the volumes are 6 million ton and 1.8 million ton, respectively.

A national organic chemical factory was built in the suburbs of Qingzhen City in the end of 1960's (Fig. 2) and started acetaldehyde-acetic acid compound plant using mercury as a catalyst in 1971. According to the announcement by the factory, production of acetic acid (HAc) was more than 9,000 ton every year, using 0.77kg of mercury per every ton of HAc. The total loss of mercury is calculated as 134.6t for 27 years, which was discharged into environment.

The wastewater containing mercury had been discharged without any treatment until 1980, but in 1981 a heavy metal absorbing facility using active carbon was introduced, which reduced mercury contamination by 95%, announced by the factory. This acetic acid process was closed in 2000 in order to switch to the petro-chemical procedure.

Guizhou Organic Chemical Factory:		
	settlement	**1971**
	product	**chemicals, especially those made from acetic acid (HAc) synthesized using mercury as a catalyst**
	quantity acetic acid production:	**9,000 t/year**
	total from 1971 to 1997	**252,676 t**
	consumption of mercury	**0.77 kg/t HAc**
	total used from 1971 to 1997	**194.6 t**
	estimated amount of mercury discharged into environment	**134.6 t**
	(according to an announcement by the Factory)	
The acetaldehyde-acetic acid compound facility was closed in 2000 in order to switch to the petrochemical procedure.		

The waste water containing mercury was discharged into a river named Zhujia(Fig. 3), which is used for irrigating the neighboring paddle field. After 3.5km downward, this river joins Dongmengqiao River at Dongmengqiao Bridge (Fig. 3). In this point, an irrigation canal diverges from the river. This canal runs about 4km providing irrigation to about 180 ha of paddle field and farmland and finally flows into Maotiao River. The structure of the canal divergence is made to introduce majority of Zhujia water into irrigation as shown in Fig. 4.

Fig. 3

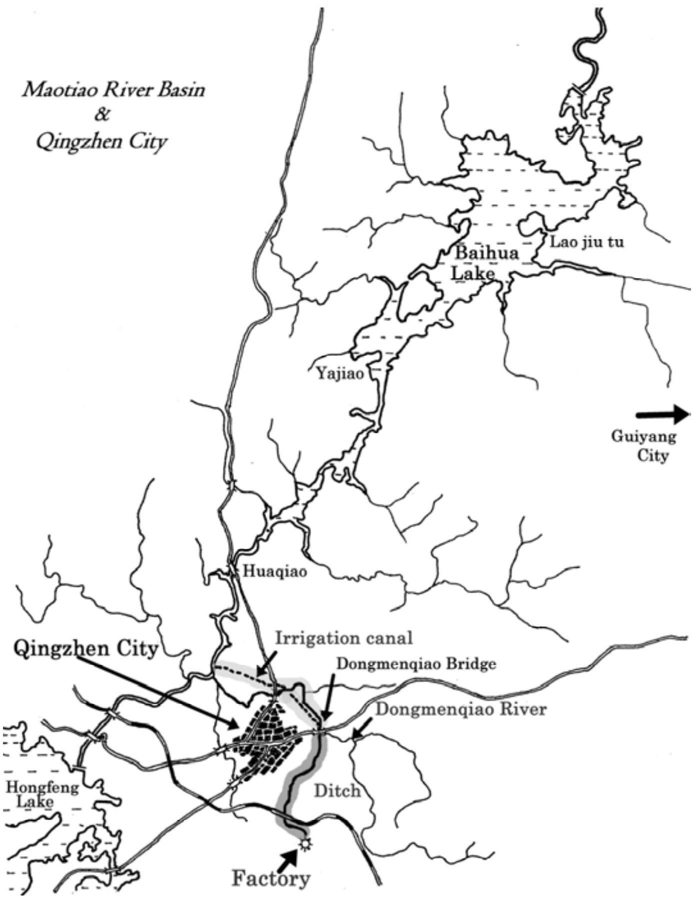
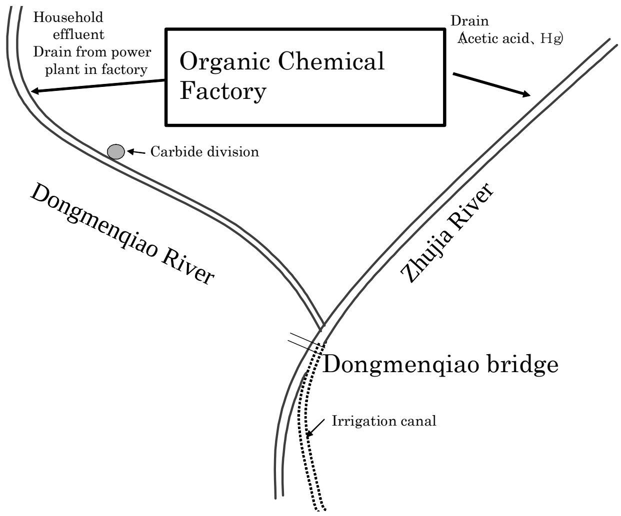


Fig. 4



Methods

Investigation was done in 3 steps. First, in order to grasp the situation of mercury distribution in the environment, water and sediment were taken at the drain ditch, start point of irrigation canal, Huaqiao, a portion of river after irrigation and Dongmengqiao River joined, Yajiao the inlet of Baihua Lake, and Baihua Lake (Laojiutu and Dam site, see Fig. 3). Second, for evaluating health impact of mercury deposit, mercury concentration of wild or hatchery fish from Yajiao and middle of Baihua Lake were checked (see Fig. 3). Simultaneously, 300 randomly selected residents in the communities distributing along the water way from Factory to Baihua Lake were interviewed their dietary habitat and health situation, as well as the hair sampling.

Finally, since those early study indicated that the soil pollution is thought as a remained problem, a systematic soil sampling along the water way was performed. Briefly, from Shanbeihou, vicinity of the waste gate, to the end of irrigation canal, 100m meshwork was laid and soil sample was taken at each cross point of meshwork using five point sampling method. Total 180 samples were collected. The sample was well mixed by quartering method and aliquot (about 50g) was taken for mercury analyses.

In the another investigation, 50m meshwork was applied on the vicinity region from Shanbeihou to Dongmengqiao. Total 96 samples were collected in this time.

Mercury analyses in water, fish meat and scalp hair were performed according to the methods described by Akagi et al. (1997).

Total mercury and methyl mercury analyses in soil and sediment samples were done according to the methods described by Yasuda et al. (2004) and Matsuyama et al. (2005), respectively.

Results and Discussion

In the preliminary investigation, a large value of mercury concentration was obtained in the water and sediment at the outlet of waste gate as shown in Table 1. However, the values were lowered downstream. On the sediment, all samples measured indicated methyl mercury deposit.

Table 1. Mercury concentration in water and sediment

Station	THg in water µg/L	MeHg in water µg/L	THg in sediment mg/kg dry wt	MeHg in sediment mg/kg dry wt
Outlet of waste gate	2.20	0.78	324.54	1.15
Inlet of irrigation	1.47	0.20	48.46	0.48
Crossing at Maotiao	0.06	-	1.16	0.01
Baihua Lake (center portion)	0.004	-	6.80	0.13
Control (Hongfeng Lake)	0.003	-	0.33	0.01

In the hatchery fish, we obtained quite low value of mercury concentration as shown in Table 2. On the other hand, the wild carnivore fish indicated relatively higher value of mercury concentration, but it is not significant data, since no control sample was obtained. In the wild herbivore fish, significantly higher value was obtained comparing to the hatchery fish. Fish mercury level was much lower than the Japanese provisional standard 0.4 ppm.

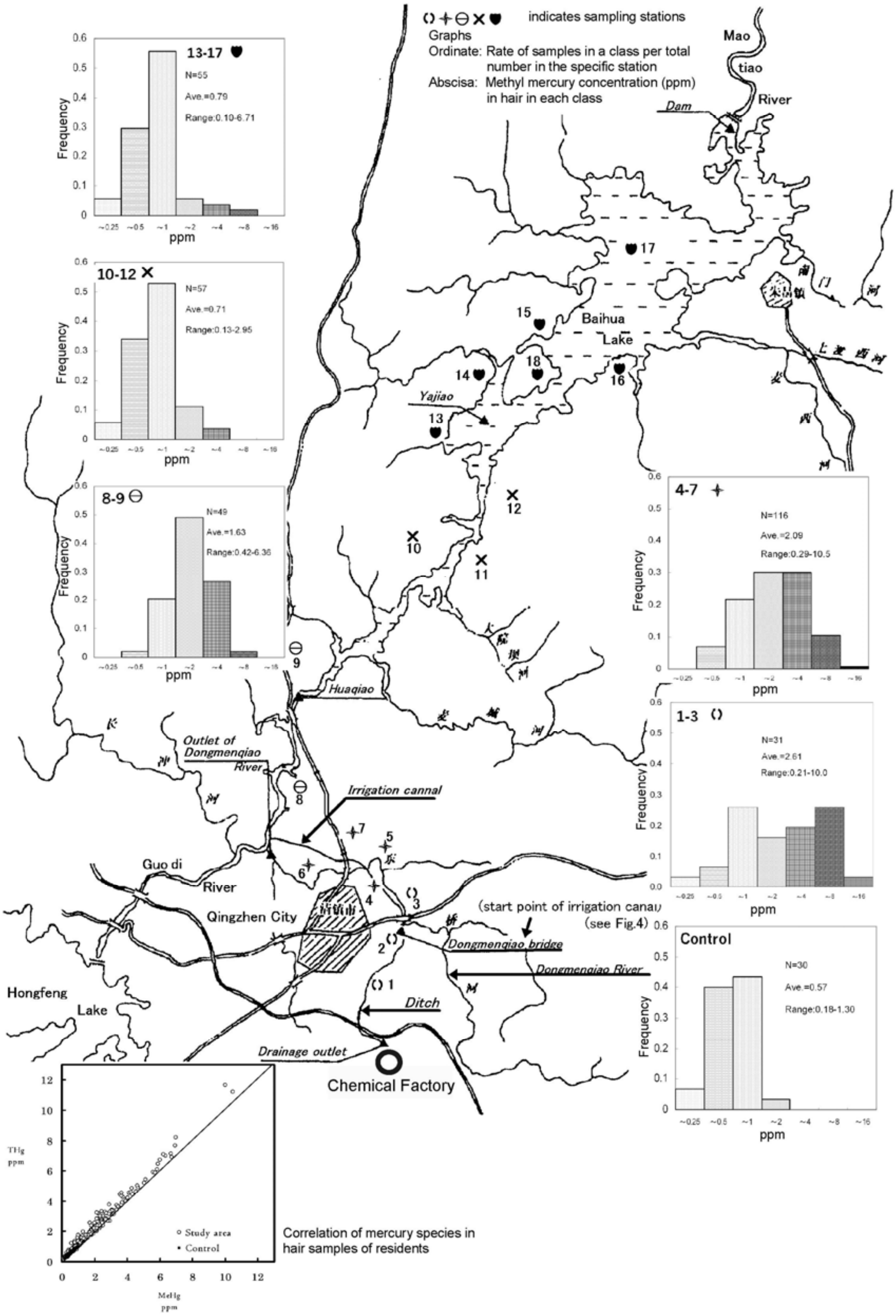
Table 2 Total mercury concentration in fish meat

Station	Sample	THg (mg/kg)
Baihua Lake	Hatchery (Carp)	0.026
Yajiao (Inlet to Baihua Lake)	Carnivore (Tirapia)	0.190
	Harbivore (Carp)	0.035
Hongfeng Lake (Control)	Harbivore (Carp)	0.030
	Hatchery (Carp)	0.024

On human hair mercury concentration, there is some difference from that in control (Fig. 6). However, even the highest value of methyl mercury was 11.5 ppm, and the average was 1.58 ± 0.17, which is lower than the limit value with no appreciable adverse effect on the offspring (14 ppm) proposed by WHO. So it is hard to think there could occur any influence of mercury to the health of residents. Those examiners were interviewed on their dietary habitat and state of health on the symptom common with the Minamata disease. People in this region scarcely take fish, instead, rice, vegetable and eggs are the daily foods.

On the other hand, there can be shown a characteristic in the distribution of mercury concentration on the topography of polluted region (Fig. 7). In this chart, tendency of gradient distribution of mercury concentration is obvious in both T-Hg and Me-Hg.

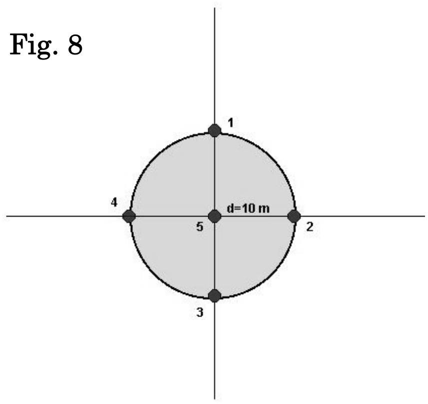
Fig. 7. Distribution of total mercury concentration in resident hair



The questionnaire investigation about dietary habitat of residents showed that majority of them eats fishes only twice or three times a week. In addition, the fishes they consume are usually bred artificially in the Lakes, which contained low level of mercury (Table 2). Therefore, it is hard to attribute the gradient of heir mercury along distance from factory (see Fig. 7) to the fish consumption. On the other hand, all the residents take rice everyday as their staple food, but data were not obtained where the rice that they consume derived from in the present study.

As mentioned previously, soil pollution of the irrigated farmland remains to be studied. Then, a 100 m meshwork was applied on the polluted field, and at each intersection along the water way, soil sample was taken (Fig. 9). As described in Materials and Methods, each soil sample was prepared after mixing five cores in each sampling station (Fig 8). The distribution of methyl mercury deposit in the study field was roughly coincides with that of total mercury as shown in Fig. 10. About 80 % of detected mercury amount was distributed in the region just vicinity of the factory waste gate (Qinglong and Xinzhai, see Figs 9 and 10). The highest value of total mercury was 200 ppm and that of methyl mercury was 0.2 ppm (Fig.10). Sum of those mercury deposits in the study field was 32 ton, if the specific gravity of soil is 1.7, and 25 ton of which is found in the high contaminated area. On the other hand, sum of methyl mercury was 25.2 kg, which indicates that the ratio of methyl mercury to total mercury is 0.08 %. In the control area, on the other hand, the ratio is 2.06 %. The reason why the ratio of methyl mercury to the total mercury is so different between the polluted region and control is not clear, however, the area polluted by mercury derived from the anthropogenic activity tend to indicate the ratio much lower than that of spontaneous one.

Fig. 8



Sample: Homogenize 1-5 cores, take 50 g

Fig. 9 Soil sampling stations on a 100 meshwork

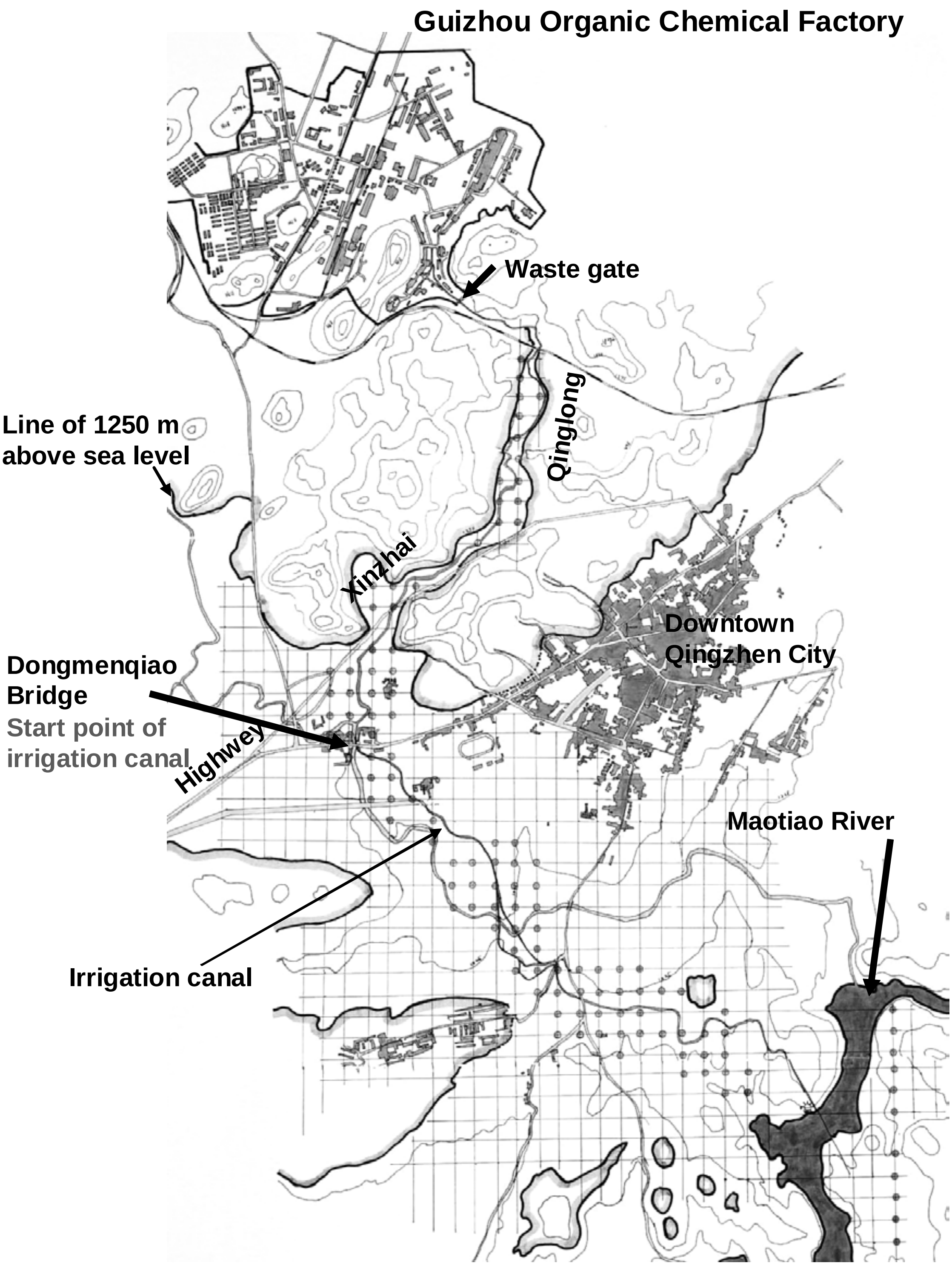


Fig. 10 Distribution of methyl mercury in Qingzhen

The majority of discharged mercury could be removed from the wastewater by sediment and/or absorption when passing through the irrigation field. In addition, because of the high concentrations of calcium or other cations in the Maotiao River water, there could be quite restricted room for mercury to be resolved when the waste joins into the Maotiao River water. On the other hand, the water in Baihua Lake continuously exchanged with the water from Hongfeng Lake, which is five times larger than Baihua Lake. The wastewater from the irrigation canal is diluted drastically by the flow from the upstream Lake. Those are the reasons why the mercury concentration level in Baihua Lake was low (Table 1).

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Mercury in Human Biomarker Materials from the Strickland-Fly Rivers Region, Papua New Guinea – Linkages to Mercury in Traditional Diets

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Centre for Environmental Health, Canberra, Australia

Communities residing at Lake Murray in Western Province, Papua New Guinea have been reported to have some of the highest concentrations of mercury in scalp hair recorded internationally for people not directly exposed to anthropogenic mercury contamination. These elevated levels of mercury, globally comparable with the Canadian Inuit and similar high fish and other aquatic food consuming communities. A number of new studies between 2000 - 2005 measuring mercury in human blood and scalp hair, confirm that the levels of mercury in hair for the highland communities is within the normal range for non-exposed populations.

The observed human mercury levels at Lake Murray have long been attributed to natural ecological processes. The lake has the ideal physical and chemical settings for mercury methylation to occur, ie an extensive shallow water body, with a maximum depth of approximately 10 metres and a mean depth of 5 metres, with a large littoral zone, surrounding wetlands, frequent wet/dry cycles, slightly acidic waters and a tropical climate.

This bioaccumulation results in high mercury concentrations in fish and other aquatic dietary items (eg turtle, crocodile). The mean mercury concentrations of fish and in particular predatory fish such as barramundi, frequently exceed the FAO/WHO recommended limit in fish intended for human consumption. The high fish consumption by the local villagers, results in mean mercury in hair values of 15 – 20 µg/g in scalp hair, with some individual values exceeding 80 µg/g.

Although there have been intermittent clinical studies of the local populations, these have consistently failed to reveal any overt signs of mercury poisoning, although a high prevalence of proteinuria (40%) was measured at Lake Murray and more recently 15 – 25% in communities living in the Middle Fly River zone. A study by Japanese researchers in 1994 measuring renal and hepatic competence using urinary nitrogen and creatinine levels identified a higher prevalence of elevated values suggesting some renal and/or hepatic disorders in the Lake Murray communities.

The present work has undertaken determination of mercury in all environmental compartments (air, water, soils and sediments) and food, including a total diet study for all of the communities living in the Strickland and Fly River systems between the highland zones and the Fly River estuary. The results for the Middle and Lower Fly River zones and Lake Murray, identified a range of food products including indigenous foods, in which the mean levels of mercury were up to two orders of magnitude higher than that generally observed in comparable total diet studies from Australia, the United Kingdom and the United States of America.

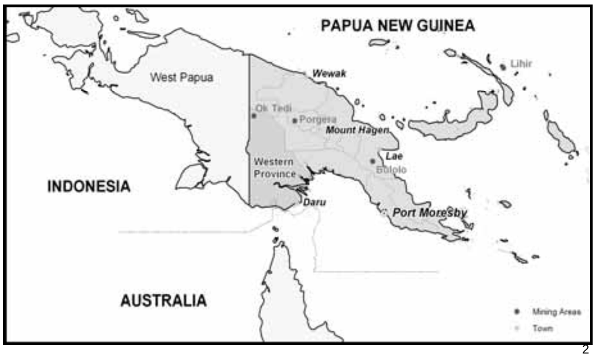
The study concludes that the elevated mercury in the local populations is not limited to Lake Murray, but also includes communities living in the Middle and Lower Fly River zones, which have similar ecological environments in the extensive chain of off-river water bodies.

Mercury in human biomarker materials from the Strickland-Fly Rivers region, Papua New Guinea – linkages to mercury in traditional diets

by
Dr Keith Bentley
Centre for Environmental Health, Canberra, Australia

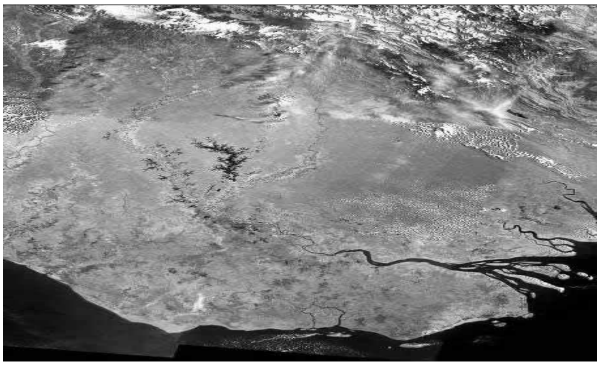
1

Map of PNG showing main gold mining locations

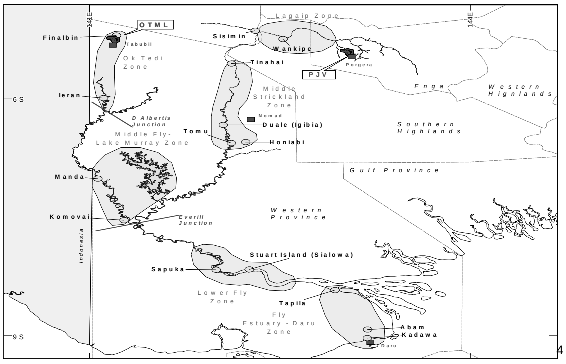


2

Satellite imagery of the Strickland-Fly Rivers and Lake Murray catchment



Report study zones highlighting areas where mercury in hair monitoring has been undertaken



4

Porgera Joint Venture Gold Mine in the PNG Highlands

Finalbin village in Star Mountains above Ok Tedi River headwaters

Lagaip River Valley (altitude 1,500 metres ASL)

7

The Strickland River 160 river kilometres downstream of the mine

8

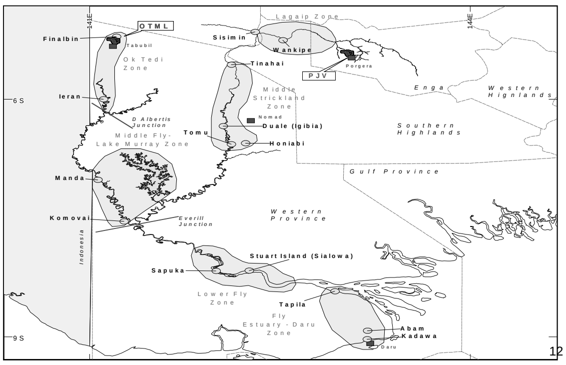
Tomu village in the Middle Strickland zone

Strickland River meandering above Lake Murray

10

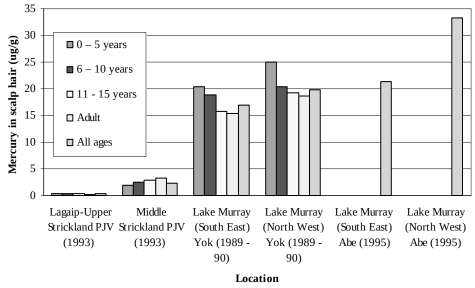
Lake Murray canoe place near Kusikina village

Report study zones highlighting areas where mercury in hair monitoring has been undertaken



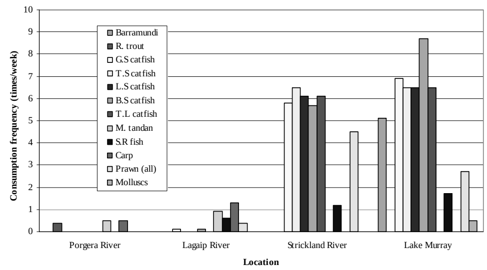
12

Levels of mercury in hair from studies in the Strickland and Lake Murray region (1989 – 1995) (all values µg/g)



13

Consumption of fish and other aquatic foods in the Porgera-Lagaip-Strickland Rivers and Lake Murray



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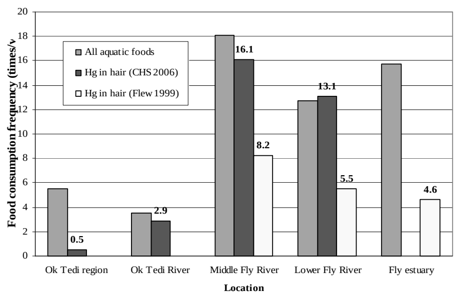
Total mercury concentrations in hair compared with consumption frequencies for aquatic foods



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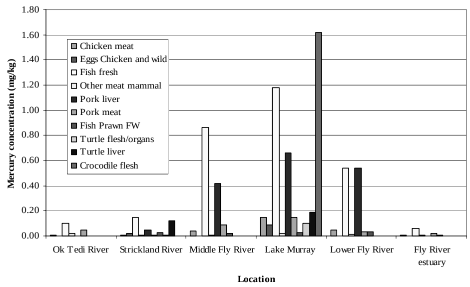
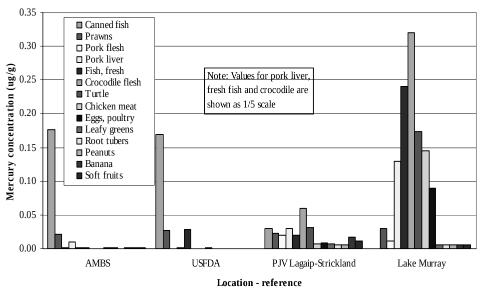
Mercury in food products in the Strickland-Fly Rivers and Lake Murray regions



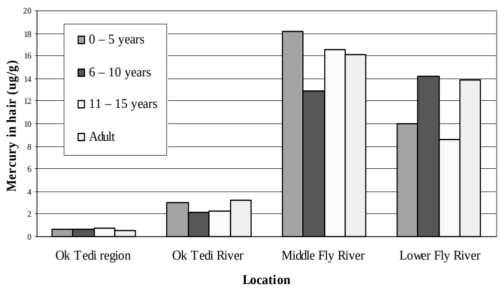
16

Mercury in food: Lagaip-Strickland villages compared with Lake Murray and total diet studies



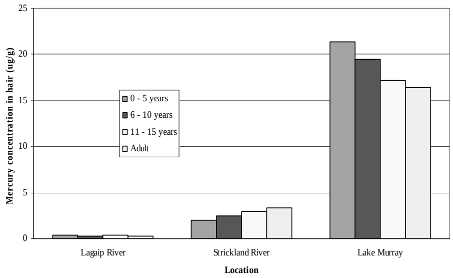
17

Mercury levels in hair for the OTML CHS 2006 study communities by age (all values µg/g)



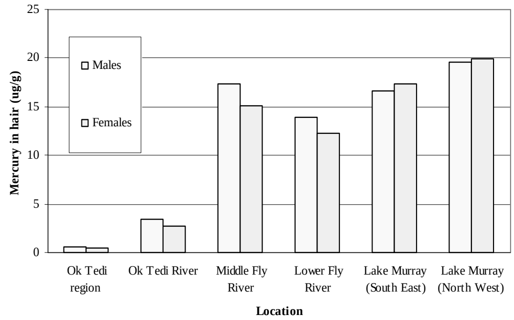
18

Mercury levels in scalp hair for the PJV HHRA 2004 study communities by age



19

Mercury levels in hair for the OTML CHS 2006 study communities by sex



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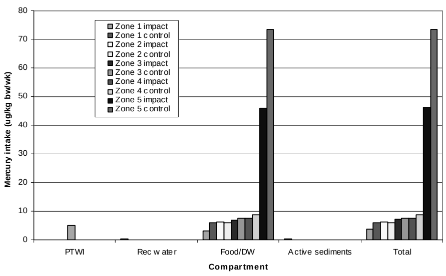
Total mercury intake for child 2 years of age from PJV HHRA



21

A Cross Sectional Survey of Hair Mercury Levels in Adult Population in Four Districts in Malaysia

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Abstract

To evaluate the current hair mercury level in Malaysia, we analyzed hair samples taken from adult population residing in two rural coastal districts of Yan (state of Kedah) and Bachok (state of Kelantan) and the urban residents of Alor Setar (Kedah) and Kota Bharu (Kelantan). This study was carried out from March to May 2006, in collaboration with the National Institute for Minamata Disease (NIMD), Minamata, Japan. During the sample collection, the Kota Bharu and Bachok Health Department, the Kedah Department of Environment, and Kampung Balai Health Clinic, Bachok assisted us. The Medical Ethics Committee, University Putra Malaysia, approved the study protocol. A total of 201 hair samples were collected from the residents living in these four districts. The National Institute for Minamata Disease analyzed the samples, using the oxygen combustion-gold amalgamation method. The geometric means for total mercury in each district were 1.38 ppm (Yan), 1.20 ppm (Alor Setar), 1.24 ppm Bachok and 1.07 ppm (Kota Bharu). The respondents were between the safe limit. According to the World Health Organization (WHO), the safe limit for total mercury in healthy adults is 50 ppm whereas for pregnant women the level should not exceed 10 ppm Two persons, each from Alor Setar and Kota Bharu, had high total mercury (washed sample 223.58 ppm and 803.16 ppm respectively). However, further analysis for MeHg showed that the levels were within the safe limit (1.36 ppm and 1.91 ppm respectively).

Keywords: hair mercury, MeHg, adult population, biomonitoring, Malaysia,

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Introduction

In environmental exposure assessments, hair samples were used as biomarkers in assessing recent exposure to methyl-mercury (MeHg) that occurred over the past several months or a year (Airey, 1983; Matsubara and Michida, 1985; Malm, et al., 1995; Canuel et al., 2006; Pinheiro et al., 2005). Blood and urine on the other hand, were invasive procedures, measured very recent exposure (such as few days prior). On the average, the hair grows 1 cm per month (USEPA, 1997). The two sources of mercury exposure in the non-occupational exposed-population are MeHg from fish consumption and inorganic mercury (I-Hg) from dental amalgam fillings.

Fifty-seven percent of the Amerindians in the French Guyana had hair mercury level exceeding 10 ppm, associated with eating carnivorous fish with mercury levels up to 1.62 ppm (Frery et al., 2001). Extensive studies by Santos et al. (2002) showed that high fish consumption (especially carnivorous fish) were linked to elevated hair mercury level among Amazon natives. The mean mercury level in hair ranged from 0.4 ppm – 49.85 ppm. The mean mercury concentration in fish ranged from 0.01 to 2.53 ppm for carnivorous species and 0.001 to 0.087 ppm for non-carnivorous.

Dental amalgam restorations continuously discharge I-Hg into the oral cavity, mostly in vapor form. Activities such as chewing, tooth brushing, drinking hot beverages or oral breathing will enhance the vapor released (Sallsten et al., 1996, Levy et al., 2004). Other routes of exposure are through breathing vapors from spills, incinerators, mercury-containing fuels, medical treatments, contaminated workplace or practicing rituals that include mercury (ATSDR, 1999). I-Hg compound are used in numerous products including various medication, germicidal soaps, teething powders and skin creams. I-Hg poisoning in adults were most commonly associated with mercury based soaps and creams especially in bleaching or skin lightening creams (Goldman and Shannon, 2001, Soo, et al., 2003). Some skin creams might contain as much as 6-10% of mercurious chloride or "calomel" (Goldman and Shannon, 2001; Counter and Buchanan, 2004).

Malaysians are at possible risk of mercury exposure through fish consumption. Factors that contribute to exposure include:

i. the Malaysia Environment Quality Report 2001 and 2004, reported that areas located in the northern part of Malaysia (Perlis, Pulau Langkawi, Kedah and Pulau Pinang), the marine water quality have more than 10% observations of mercury levels exceeding the Malaysian Interim Marine Water Quality Standard of 0.001 mg/l (Table 1). Mercury can be transformed into methyl mercury (most common and toxic form of mercury) by microorganisms in marine sediment and biomagnified in predatory animals.

Table 1: Percentage of observations for parameter mercury exceeding the Malaysian Marine Water Interim Standards for seven selected locations in Malaysia (1999 – 2004) (EQR 1999-2004, Malaysia)

Location	% Observation for Parameter Hg Exceeding Interim Standards					
	1999	2000	2001	2002	2003	2004
PERLIS	-	50	-	50	25	23
LANGKAWI	-	33	-	26	12	29
KEDAH	-	58	-	50	0	27
PENANG	-	34	-	20	13	10
KELANTAN	-	0	-	0	0	0
TRENGGANU	-	2	-	0	18	1
Average for Malaysia	6.5	17.3	8.7	12.6	12.7	10.8

ii. Fish is an important food item which contributes about two-thirds of all meat consumed in the country. Our annual fish consumption is as high as 57.7 kg/year (Laurenti, 2002). Over 90% of the national fish catch is from sea (Mohd. Arshad and Mohd. Noh, 1994). Fish is at the top of the aquatic food chain, bio-accumulated methyl mercury approximately 1-10million times greater than dissolved Hg concentrations found in surrounding waters (USEPA, 2001). Agusa et al. (2005a) reported that some specimens of marine fish caught in the Straits of Malacca had mercury levels higher than the guideline value imposed by the USEPA.

Currently in Malaysia, there are limited studies on mercury level using scalp hair. Sivalingam and Sani (1980) carried out a study in fishing communities in the State of Penang and they found that the sampled populations were not exposed to high levels of mercury. Sarmani et al. (1994) reported the median mercury level in Terengganu communities were higher than in Penang, 12.05 ppm and 2.96 ppm respectively. The elevated mercury level was attributed to high fish consumption. Sarmani et al. (2002) also reported that mercury level varied according to race. The median values for total mercury in hair samples were 2.74 ppm for Malays, 3.81 ppm for Indians and 4.50 ppm for Chinese (Table 2). Foo et al. (1988) studied the Singapore residents and reported the arithmetic means of total mercury level of 6.1 ppm for Chinese, 5.2 ppm for Malays and 5.4 ppm for Indians. They suspected that the higher mercury level found among the Chinese was probably due to traditional ethnic medicines. In Japan, males had higher total mercury compared to female (geometric means 2.55 ppm and 1.45 ppm, respectively, Yasutake et al., 2003). According to The World Health Organization, no adverse health effects were observed for hair mercury levels below 50 ppm (WHO, 1990). However, for pregnant women, the level should be below 10 ppm. The Americans has adopted a more conservative value, the reference dose (RfD) for MeHg is 0.1 µg/kg- body weight/day (USEPA, 1997). This level corresponds to 1 µg/g hair mercury concentration.

The objective of this study is to assess the current hair mercury levels among adults in selected areas in Kedah and Kelantan . We hope that our results will contribute to the establishment of reference values for mercury levels in hair in Malaysia.

Table 2: Previous mercury studies in Malaysia

State	N	Range (or highest level) (ppm)	Arithmetic Mean (ppm)	Median (ppm)	Reference
Penang	80	12.8 (aged <18 years) 14.8 (aged 19-40 years) 16.1 (aged >41 years)	7.36 7.9 9.19		Sivalingam & Sani (1980)
Selangor	35		4.3 (rural) & 9.0 (urban)		Sarmani et al. (1984)
Kuala Lumpur	25	2.06 - 16.40	6.62 $\pm$ 3.73	7.03	Sarmani (1987)
Sepang	20	1.21 - 7.97	4.34 $\pm$ 2.39	4.24	
Alor Setar	40	0.20 - 1.52	0.82 $\pm$ 0.31	0.89	
Overall	85	0.20 – 16.40	3.36 $\pm$ 3.60 2.97 $\pm$ 6.57 (GM)	1.24	
Penang		0.45 – 16.68	3.61; 3.49 (GM)	2.96	Sarmani et al. (1994)
Trengganu		6.79 - 18.31	12.08; 11.69 (GM)	12.05	
Penang	106	0.20 - 5.80	1.11		Sarmani et al. (1994) (quoted in Sarmani & Alakili, 2004a)
Selangor	45	0.66 - 6.90	3.01		
Trengganu	33	6.79 - 18.31	12.08		
By Race:					Sarmani et al (2002) & Sarmani & Alakili (2004a)
Malay		0.83 – 15.30	3.07	2.75	
Indian		0.59 – 18.73	4.43	3.81	
Chinese		0.91 – 15.69	5.12	4.50	
Overall : (Kuala Lumpur)		400	0.59 - 18.73	4.01	
Malaysians	400	0.59 – 18.73		3.38	Sarmani & Alakili (2004b)
Libyan	50	0.0 – 3.6		0.81	
Jordan	22	0.32 – 4.00		0.69	

Methodology

This study was carried out from March to May 2006, in collaboration with the National Institute for Minamata Disease (NIMD), Minamata, Japan, Kota Bharu and Bachok Health Department and the Department of Environment of Kedah and Kelantan and Kampung Balai Health Clinic. The Ethics Committee, Universiti Putra Malaysia, approved the proposal for this study. Informed consents were obtained from the participating subjects before the commencement of the study. The mercury results were sent to all participants and those who recorded high mercury level were advised to consult the medical personnel.

Study location:

Two coastal rural areas, Yan (State of Kedah) and Bachok (State of Kelantan), are located on the western and eastern sides in the northern part of Peninsular Malaysia, were selected (Figure 1). Yan was chosen as it is located in the area reported to exceed the Malaysia interim marine water quality standard for mercury. Two fishing villages: Kampung Keda and Kampung Sungai Udang were chosen for this study. Although Kelantan did exceed the interim standard, we choose this area because some of the fish eaten were imported from the neighbouring state, especially during the monsoon season. Bachok is one of the most active fishing villages in Kelantan. Kampung Balai was selected for the study. In both areas, majority of the residents are fisherman. The urban residents of Alor Setar (State of Kedah) and Kota Bharu (State of Kelantan) were chosen as comparison groups.

Exposure assessment survey

Fifty adult respondents from each area were recruited. With the help of a nurse and health inspectors, we sampled their scalp hair and distributed mercury exposure questionnaires. The questionnaire contains information such as age, gender, race, weight, height, fish consumption (the quantity and frequencies of consumption), the number of amalgam dental fillings (if they had any), current or past occupations, use of skin lightening-cream, traditional medicine, and history of hair waiving. The frequency of fish consumption was recorded as “everyday”, “sometimes”, “rare” and “never eat” (if less than a meal/year). An “ikan kembung” (Indian Mackerel) measuring 19.5 cm by 5.0 cm, 70g in weight was used during the survey to guide the participants in determining the weight of fish consumed. All samples were sent to the National Institute for Minamata Disease (NIMD), Minamata City, Japan. The total mercury levels were determined by oxygen combustion-gold amalgamation method using an atomic absorption detector MD-1. The limit of detection was 0.05 ng mercury.

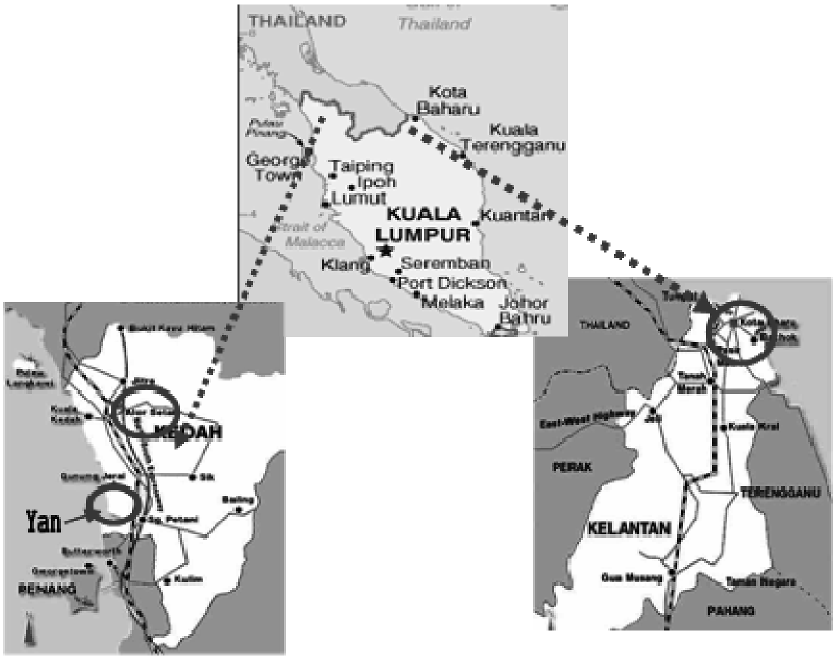


Figure 1: Map of Malaysia and sampling locations

All statistical analysis were performed using the SPSS Version 12. The total amount of daily intake of fish and shellfish is estimated from the serving frequency and the amount of fish and shellfish consumed in each serving.

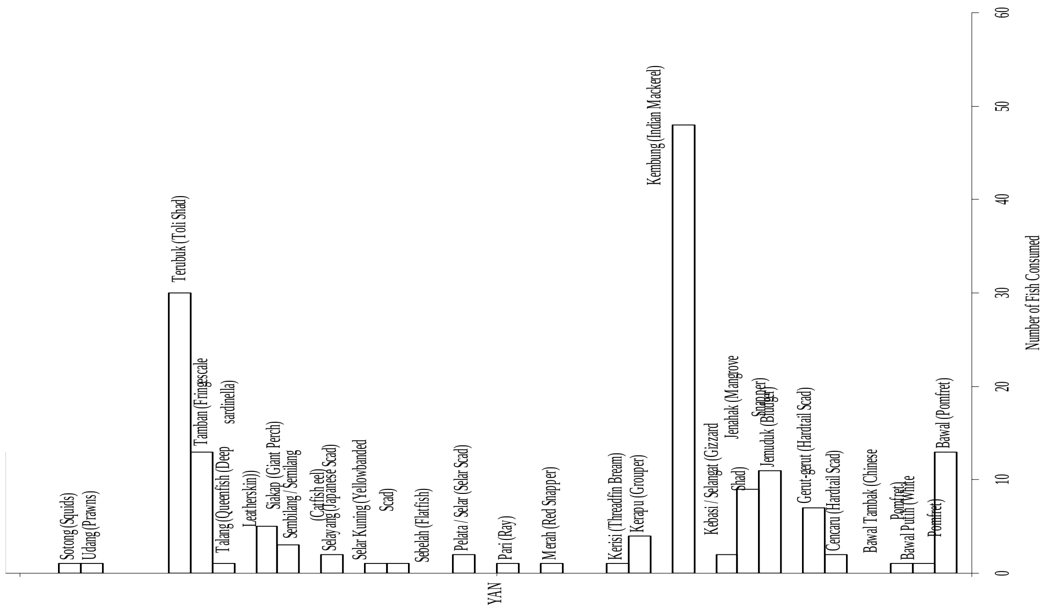
Results

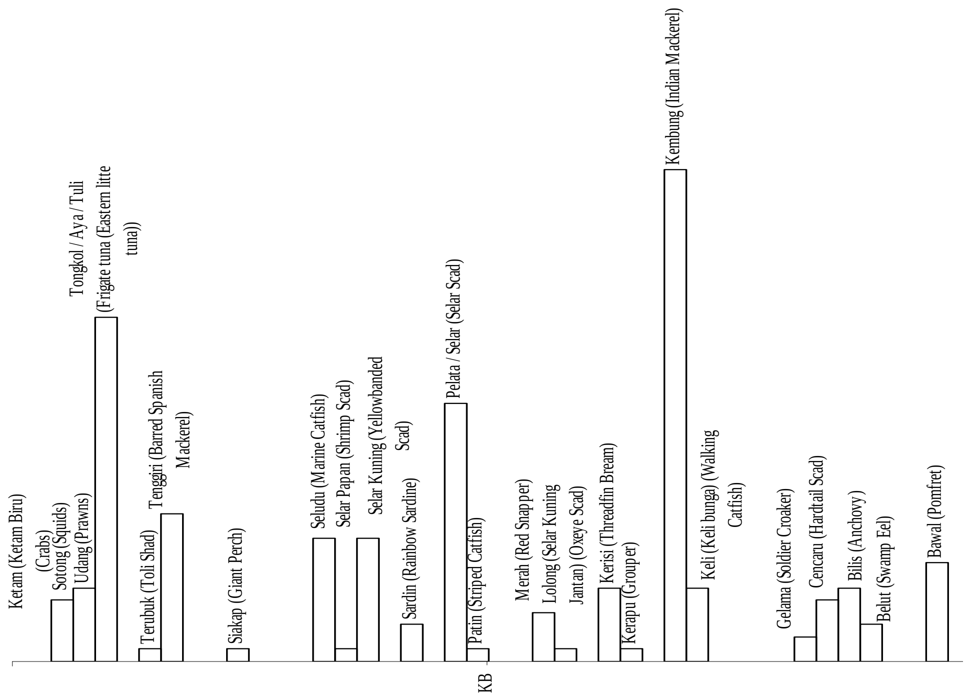
Demographic characteristics

There were 201 samples of scalp hairs donated by donors (50.7% female and 49.3% male). The Malays constitute 96.5% (n = 194) of the studied population while 2.0% (n = 4) Chinese and 1.5% (n = 3) Siamese. Thus, the findings of the study were reflective of the Malay ethnic communities. The participants' ages ranged from 18 to 72 years old (mean = 40.6). The mean ages for Yan and Bachok participants were 47.3 and 43.7 years old, respectively, while for the Alor Setar and Kota Bharu participants, the mean age were 35.1 and 36.3 years, respectively. The majority of the study population (64.7 %) had an annual household income of below RM10, 000 (Table 1).

Fish consumption characteristics

Fish consumption in the study ranged between 1.7 to 999.0 g/person/day with 60.3% consumed less than 150 g/day of fish. Average fish consumption for the study population was 180.19 $\pm$ 11.34 g/ day/person with the median of 140.00 g/person/day. The Yan and Bachok (rural) communities consumed an average of 331.21 g/day and 179.51 g/day while for Alor Setar and Kota Bharu (urban) communities was 110.88 g/day and 96.39 g/day, respectively. The urban residents consumed less fish compared to the rural residents. Ninety-eight percent in Yan, 78% in Alor Setar, 96% in Bachok, and 68% in Kota Bharu consumed fish between one to five servings/day. Figure 2 and 3 illustrates the types of fish consumed by the participants according to the location of study and gender. Based on the respondents' feedback, most of the participants consumed mainly non-carnivorous, medium-sized (below 30 cm) marine fish. Further breakdown of fish consumption pattern among locations varied slightly. The top four most popular fish consumed by the east coast residents of Kota Bharu residents were Indian mackerel (*Restrelliger sp*.), Frigate tuna (Eastern little tuna) (*Auxis thazard*), Barred Spanish Mackerel (*Scomberomorus sp*), and Selar Scad (*Selar sp*.). For Bachok residents, Indian mackerel (*Restrelliger sp*.), Japanese Scad (*Decapterus maruadsi*), Selar Scad (*Selar sp*.), and Frigate tuna (Eastern little tuna) (*Auxis thazard*). For the west coast residents of Alor Setar, Indian mackerel (*Restrelliger sp*.), Anchovy (*Stolephorus sp.)*, Pomfret (*Pampus sp*.), and Red Snapper (*Lutjanus sanguineus*). For Yan residents, Indian mackerel (*Restrelliger sp*.), Barred Spanish Mackerel (*Scomberomorus sp*), Pomfret (*Pampus sp.*), and Fringescale sardinella (*Sardinella fimbriata*). In general, the rural residents preferred smaller-size fish (below 30 cm). The Indian Mackerel topped the list. The Frigate tuna (Eastern little tuna) (*Auxis thazard*) (above 30 cm) were popular only among the east coast residents.


Sotong (Squids)
Udang (Prawns)
Terubuk (Toli Shad)
Tamban (Fringescale sardinella)
Talang (Queenfish (Deep Leatherskin))
Siakap (Giant Perch)
Sembilang / Semilang (Catfish eel)
Selayang (Japanese Scad)
Selar Kuning (Yellowbanded Scad)
Sebelah (Flatfish)
Pelata / Selar (Selar Scad)
Pari (Ray)
Merah (Red Snapper)
Kerisi (Threadfin Bream)
Kerapu (Grouper)
Kembung (Indian Mackerel)
Kebasi / Selangat (Gizzard Shad)
Jenahak (Mangrove Snapper)
Jemuduk (Bludger)
Gerut-gerut (Hardtail Scad)
Cencaru (Hardtail Scad)
Bawal Tambak (Chinese Pomfret)
Bawal Putih (White Pomfret)
Bawal (Pomfret)
YAN
0
10
20
30
40
50
60
Number of Fish Consumed


Ketam (Ketam Biru) (Crabs)
Sotong (Squids)
Udang (Prawns)
Tongkol / Aya / Tuli (Frigate tuna (Eastern litte tuna))
Terubuk (Toli Shad)
Tenggiri (Barred Spanish Mackerel)
Siakap (Giant Perch)
Seludu (Marine Catfish)
Selar Papan (Shrimp Scad)
Selar Kuning (Yellowbanded Scad)
Sardin (Rainbow Sardine)
Pelata / Selar (Selar Scad)
Patin (Striped Catfish)
Merah (Red Snapper)
Lolong (Selar Kuning Jantan) (Oxeye Scad)
Kerisi (Threadfin Bream)
Kerapu (Grouper)
Kembung (Indian Mackerel)
Keli (Keli bunga) (Walking Catfish)
Gelama (Soldier Croaker)
Cencaru (Hardtail Scad)
Bilis (Anchovy)
Belut (Swamp Eel)
Bawal (Pomfret)
KB

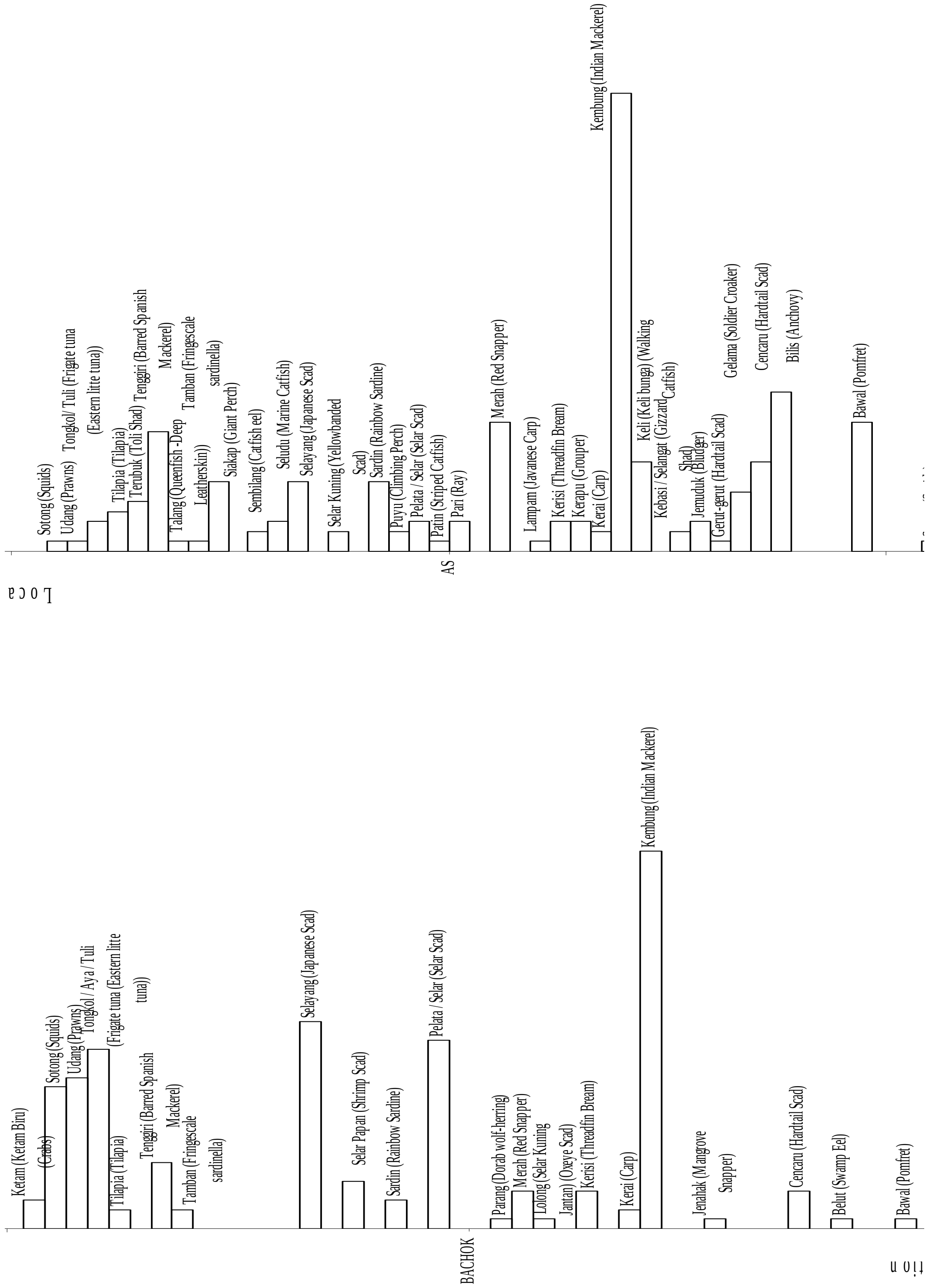


Figure 2: Types of fish consumed

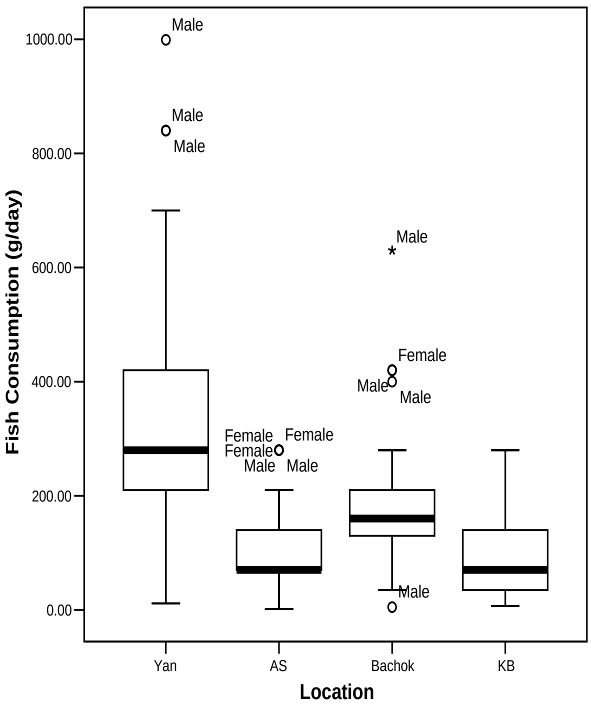


Figure 3: Comparison of fish consumption by location and gender

Hair mercury results

The geometric means for hair mercury (unwashed) for all locations ranged from 1.07 ppm – 1.38 ppm. The spread of mercury reading in Alor Setar is large because there was one person who recorded the maximum concentration of 646.79 ppm. One participant (KB046) was excluded from the analysis because the unwashed sample was not analyzed (total mercury possibly exceeding 1000 ppm). The descriptive statistic for the total mercury according to location is shown in Table 3. Further breakdown into gender revealed that there is no significant difference between total mercury concentrations in gender in all locations ($p<0.25$) although the geometric mean in male in Yan is the highest (1.69 ppm). Comparison of total mercury concentration between gender at all locations is shown in Tables 4 and 5. From the study, the total mercury increases with age. There is a significant relationship between hair mercury and age ($p<0.038$). One person in the age group 20-29 recorded the highest mercury level. The total mercury concentration against age is shown in Figure 4. This study also found a significant relationship between fish consumption and hair mercury level.

Table 3: Demographic profile of participants

Variable		Location							
		Yan (n=50)		Alor Setar (n=50)		Bachok (n=51)		Kota Bharu (n=50)	
		n	%	n	%	n	%	n	%
Gender	Female	17	34	29	58	25	49	31	62
	Male	33	66	21	42	26	51	19	38
Race	Malay	49	98	50	100	46	90.2	49	98
	Chinese	1	2	0	0	2	3.9	1	2
	Indian	0	0	0	0	0	0	0	0
	Others	0	0	0	0	3	5.9	0	0
Age	Range	21 - 72		19 - 52		18 - 64		20 - 53	
	Mean	47.26		35.12		43.74		36.3	
BMI	Underweight	2	4.1	3	6.1	1	2	2	4
	Normal	26	53.1	23	46.9	29	56.9	27	54
	Overweight	15	30.6	16	32.7	16	31.4	17	34
	Obesity	6	12.2	7	14.3	5	9.8	4	8
Income(RM)	<RM10,000	46	92	17	34	41	80.4	26	52
	10,000 -20,000	3	6	17	34	4	7.8	5	10
	20,000 - 30,000	1	2	8	16	4	7.8	14	28
	30,000 - 40,000	0	0	3	6	2	3.9	3	6
	40,000 - 50,000	0	0	2	4	0	0	1	2
	> 50,000	0	0	3	6	0	0	1	2

Table 4: Total mercury concentration (unwashed samples) in all location

Statistic	Total mercury (ppm)			
	YAN (n=50)	ALOR SETAR (n=50)	BACHOK (n=51)	KOTA BHARU (n=50)
Geometric Mean	1.38	1.20	1.24	1.07
Arithmetic Mean	1.58	14.14	1.46	1.28
Std. Error of Mean	0.14	12.91	0.16	0.13
Q1 (Percentile 25)	0.97	0.82	0.88	0.77
Q2 (Median)	1.33	1.01	1.20	0.92
Q3 (Percentile 75)	1.89	1.54	1.63	1.32
Min	0.53	0.34	0.48	0.40
Max	5.37	646.79	6.61	4.20

Table 5: Total mercury concentration (unwashed) in all locations by gender

	Total mercury (ppm)							
Statistic	Yan		Alor Setar		Bachok		Kota Bharu	
	Female (n=17)	Male (n=33)	Female (n=29)	Male (n=21)	Female (n=25)	Male (n=26)	Female (n=30)	Male (n=19)
Geometric Mean	0.93	1.69	1.36	1.01	1.31	1.1797	1.03	1.15
Arithmetic Mean	0.98	1.89	23.59	1.10	1.60	1.3231	1.22	1.36
S.E Mean	0.08	0.18	22.26	0.11	0.29	0.1381	0.16	0.21
Q1 (Percentile 25)	0.69	1.29	0.83	0.77	0.91	0.7425	0.76	0.76
Q2 (Median)	0.90	1.59	1.07	1	1.26	1.045	0.84	1.07
Q3 (Percentile 75)	1.21	2.11	1.55	1.175	1.57	1.69	1.23	1.46
Min	0.53	0.63	0.34	0.46	6.61	0.63	0.43	0.40
Max	1.94	5.37	646.79	2.5	6.13	3.48	4.20	4.19

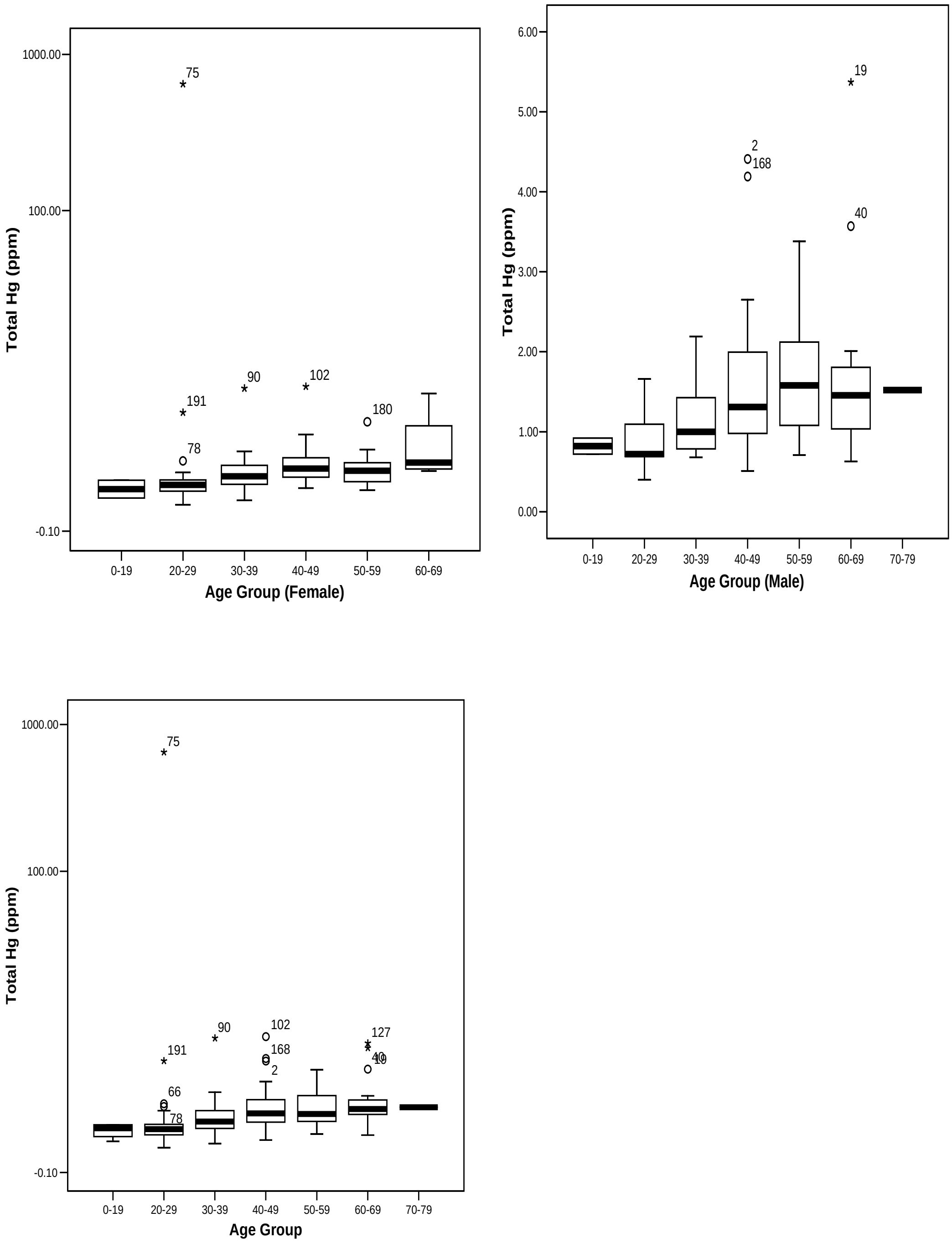


Figure 4: Total mercury concentration (unwashed) by gender and age

In this study, 58.7% of the population exceeded the 1 ppm value recommended by USEPA. However, if we were to compare with the WHO standard (50 ppm), all were within the safe limit except for two individuals (AS025 & KB046). For further analysis, six individuals were selected for MeHg analysis. The total mercury obtained from the washed samples ranged from 3.27 ppm to 803.16 ppm (Table 6). The MeHg concentration ranged from 0.54 ppm to 4.52 ppm.. The percentage of MeHg ranged from 0.24% - 96.64% of the total mercury concentration. Two participants (AS025 and KB046) had the highest total mercury concentration (223.58 ppm and 803.16 ppm) but the percentage of MeHg is low (0.61% and 0.24%). Three participants (KB017, Y019 and Y033) had high MeHg, 72.90%, 84.64%, and 96.64% respectively.

Table 6 : Percent of MeHg (washed sample) from the total mercury

Subject	Total Hg (ppm) (washed sample)	Me-Hg (ppm)	%MeHg in the hair's total Hg
Y019	5.34	4.52	84.64
Y033	3.27	3.16	96.64
AS025	223.58	1.36	0.61
B002	4.4	0.54	12.27
KB017	4.17	3.04	72.90
KB046	803.16	1.91	0.24

Discussion

The US National Research Council has suggested a RfD MeHg of 0.1µg/kg bodyweight/day (NRC, 2000) which corresponds to the hair mercury of 1 ppm (Yasutake et al., 2003, and Johnson et al. 2004). In this study, 58.7% of the population exceeded the 1 ppm value although the level of MeHg analysis on six subjects revealed that it was still low. The RfD of 0.1 µg/kg body weight based on a study in Faroe Island, Denmark. The RfD would not be exceeded by eating 3 meals of 100g each week of fish with a mercury level of 0.1 ppm. This means that if a person weighed 50 kg body, he should not exceed intake of 5 µg/day.Yasutake et al. (2003) pointed out that hair mercury level in fish eating countries, such as Japan, would be higher than 1 ppm. They suggested that it would not be appropriate to adopt that level. Agusa et al. (2005a) showed that 48% of marine fish from Malaysia had mercury levels higher than the guideline value calculated from the RfD and 50 kg body weight (i.e 5 µg/day). WHO (1990) suggested a less conservative mercury concentration of 50 ppm in hair samples from subjects with high fish consumption, which was associated with a 5% risk of neurological lesions in adulthood, while the maternal hair mercury level not exceeding 10 ppm. The rate of fish consumption (180.19 $\pm$ 11.34 g/day/person) or equivalent to 65.8 kg/year in this study was higher than was reported by Laurenti (2002) and Earth Trends (2003), 57.7 kg/year and 58 kg/year respectively (equivalent to 158.08 g/person/day).

Overall, the present study found that the level of mercury in hair was still low compared to previous studies. However, the maximum mercury level in this study (up to 646.79 or more than 1000 ppm (for KB046) was higher than observed by Sarmani et al. (2004) , which was 18.73 ppm. The median total mercury were quite low in this present study although the maximum range for the urban residents were higher than found by Sarmani et al. (2004).

This study found a significant relationship between fish consumption and hair mercury level. This is in agreement with previous studies (Foo et al., 1988; Sarmani and Alakili, 2002; Sarmani and Alakili, 2004; Patch et al, 2005). Canuel et al. (2006) reported low mercury hair level among Canadian ethnic groups postulating the effect of genetic characteristics. Eating large carnivorous fish were implicated with elevated hair mercury levels (Malm et al., 1995; Dolbec et al., 2001). Most of the participants in our study consumed mainly non-carnivorous, medium-sized marine fish.

From this study, we detect no gender difference in mercury level. Gender differences in hair mercury varied greatly among reports (Barbosa, et al., 2001). Some studies showed that gender was not likely to be an important factor in determining the hair mercury level (Mortada et al., 2002; Olivero et al., 2002) while Sarmani ans Alakili (2004) and Foo et al. (1988) reported gender as one of the determining factor. Lebel et al. (1998), Barbosa et al. (2001) and Agusa et al. (2005) did not find any gender differences in hair mercury. In contrast, Barbosa et al. (2001), Johnsson et al. (2004) reported lower levels in female hair while Foo et al (1988), Batista et al. (1996) and Yasutake et al. (2003) reported the opposite.

Our study indicates that mercury level increases with age. Sarmani and Alakili (2004) reported that age is another factor that influences the hair mercury level. It is interesting to note that women at childbearing age (16-40 years old) had a substantially lower concentration of hair mercury (organic and inorganic) due to pregnancy and lactation (Barbosa et al., 1998) although their recent study in 2001 did not reveal the same results. Yasutake et al. (2003) observed an increased in hair mercury in male up to the age of 50-60 years old which is also observed in this study but the female levels showed a reduction at the age of 20 which is not observed in this study. Foo et al. (1988) and Sarmani et al. (2002) found lower mercury levels in the Malays compared to other races. Sarmani and Alakili (2004) and Foo et al. (1988) reported that ethnicity influence the hair mercury levels most probably to different dietary intake. We were not able to observe the race effect because majority of our participants were Malays.

Great variations were observed when comparing the percentage of MeHg in the total hair mercury. In this study, we discovered that the percentage of MeHg in the total mercury ranged between 0.24 – 96.64%. Foo et al. (1988) found low levels of total hair mercury (4.5 – 6.1g/g) among the

Chinese and Malays and the Indian ethnic group had a relatively low percentage of hair MeHg (49 – 55%). Lebel et al. (1996) stated that the MeHg is in the range of 72.2-93.3% of the total mercury while Sarmani and Alakili (2004) reported 0 %– 75.81%.

In this study, all samples were not washed prior to analysis. It is recommended that the samples should be washed thoroughly prior to analysis to eliminate any outside contamination. However, Foo et al.(1988) stated that there was no appreciable difference between washed and unwashed hair samples although it was necessary for the samples to be washed prior to analysis for people with occupational exposure as mercury can be readily absorbed into the hair follicles. Twenty four samples were selected and washed and six of them were tested further for methyl mercury. The 24 samples selected, both tested for total mercury, with and without washings, revealed that 25% of the samples were contaminated by cosmetics (data not shown). The skin lightening cream is the most significant variable that can be used to explain the variation in the hair mercury.

Two female donors, one each in Alor Setar (AS025) and Kota Bharu (KB046), had a very high level of hair mercury, 646.79 ppm and “not determined” (most probably more than 1000 ppm) (personal communication with Dr.Yasutake) respectively while their washed samples reveals that the total mercury was 223.58 ppm and 803.16 ppm. This indicates that the contamination was due to inorganic mercury. Exposure from the air seemed less probable because all lady participants wore head scarf. Majority of participants using skin lightening cream were female (63 female and 7 male). In this study, 56 females were currently use skin-lightening creams are of childbearing age. However, their risk is small because adsorption of inorganic mercury through skin is minimal.

Five female donors (one person each from Yan, Alor Setar and Kota Bharu and another two from Bachok) were pregnant (2 months-8 months) had mercury levels ranged from 0.82 ppm to 4.20 ppm and one up to more than 1000 ppm (KB046). Follow-up on subject KB046 showed that she gave birth to a healthy baby boy in June 2006. We recommended to women in this study to go for urine mercury analysis as an increase in urine mercury concentration was observed in women who used skin lightening cream (Weldon et al., 2000, Del Giudice and Vyes, 2002; Soo et al., 2003) .

Among the shortcomings, we were not able to recruit more people due to financial constraints. However, we were assisted by several government agencies making subject recruitment easier. On hair sampling, hair samples taken from male participants (especially in Yan) were very short (less than 1cm in length), thus the hair was cut very close to scalp whereas in females donors, most hairs were cut at about 3 cm from the scalp and 10 cm in length . This will gives us the exposure period of about 1 – 1.5 years as the hair grow at about 1cm/month. For male donors, only recent exposure (of maybe 2 months) was reflected in the analysis. We also realized that when we forwarded our sample for analysis, we did not indicate which part of the hair is closer to the root. We do not know whether it will affect the mercury result. According to Barbosa et al. (2001), he used the cotton thread to bundle the hair before placing in envelope while taped the hair to indicate the portion near to the root. This is necessary if the hairs were from donors with waiving cream effect. A proximal portion of hair is suitable rather than a distal part for MeHg estimation. The reason is that the contents of MeHg might decrease during growth of hair under certain conditions including treatment with artificial hair waving (Yasutake et al, 2003).

Conclusion

From our study we found that the total hair mercury levels were within the save limits if we were to compare with the WHO standard (50 ppm), except for two female participants Further analysis on them revealed that the MeHg concentration was low.

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Mercury Exposure to Workers at Gold Mining and Battery Plants in Vietnam

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Abstract:

To obtain the fundamental information of human exposure to mercury (Hg) due to gold mining activities and industrial pollution in Vietnam, total mercury was determined in human hair, plasma, red blood cells (RBCs), and urine samples collected from 282 workers at the gold mining areas and battery plants. The results indicate that total mercury (T-Hg) concentration in hair, plasma, RBCs and urine are from 1.18 to 16.65ppm, 6.80 to 31.24 ppb, 26.91 to 38.06 ppb and 9.80 to 51.20 ppb, respectively. The mercury concentration in plasma of the battery plant workers is higher than that of the gold miners. On the contrary, the mercury concentrations in RBCs and hair of plant workers are lower than that of the gold miners. Good correlations in mercury concentrations were found between hair and RBCs samples of the gold miners and between urine and plasma samples of the battery plant workers.

Keywords: mercury, gold mining, battery plants

Introduction

Environmental mercury pollution due to gold mining and industrial activities in Vietnam has been concerned in recent years. In the gold mining processes an enormous amount of metallic Hg has been used and released in an abusive way into local ecosystems over the last 15 years, of which are discharged in to river system and the atmosphere. Owing to this metal, therefore, there is a possibility of causing two types of health hazards in near gold mining: firstly, accumulation inorganic mercury poisoning by direct inhalation of mercury vapour during the processes of burning and re-burning Hg-Au amalgam. Secondly, a part of mercury discharged into river system is methylated and ultimately bio-accumulated to a significant level in fish. Thus, people living along the river and depending on riverine products are easily exposed to methyl mercury (MeHg) and may develop toxically levels through repeated consumption of these contaminated fish. The people living near gold mining areas may be contaminated with at least two forms of Mercury - Inorganic Hg and MeHg - simultaneously from surrounding air and diets [1,2,6], but the workers at the battery plants were contaminated with only inorganic mercury from battery production.

Therefore, the present study aimed at evaluating the actual human exposure to Hg due to gold mining activities and battery production by measuring total mercury in human hair, urine, RBCs and plasma samples collected from people living in gold mining areas and battery plants.

Materials and methods

Samples

Human hair, urine, RBCs and plasma were used in this study; the samples were collected from the inhabitants living in gold mining and battery plants of Vietnam. The subjects consisted of 270 males and 12 females. The health assessment as well as personal data (age, sex, address and occupation) was obtained at the time of sampling.

Analytical procedures for mercury

In the present work, the determination of total mercury was made with sensitive and reliable methods recently developed in National Institute for Minamata Disease (H. Akagi et al 2001) [1, 2, 3, 4, and 6]

Total mercury analysis in hair samples: The procedure for total mercury in hair is shown in Fig.1. A known amount of 10mg hair sample was placed in a 50 ml volumetric flask, to which 1 ml of water, 2 ml of concentrated nitric/perchloric acid (1:1) and 5 ml concentrated sulfuric acid were added and heated at 200^{o} C on a hotplate for 30 min. After cooling until the room temperature, the digested sample was made up to 50 ml with mercury-free water. An aliquot of sample solution was introduced into an automated circulating air flow system with the addition of 10 % stannous chloride solution ($SnCl_2$). After air circulation for 30 s, the mercury in circulating air was measured by cold vapour atomic absorption spectrometry. The detection limit is around 0.5 ng.

Total mercury analysis in blood (RBCs and plasma) samples: The procedure for total mercury in blood is shown in Fig.2. The 500-mg of blood sample was weighed, sample was placed in the 50-ml volumetric flask, to which 1 ml of water, 2 ml of concentrated nitric/perchloric (1:1) and 5 ml of concentrated sulfuric acid were added and heated at 200^{o} C on a hotplate for 30 min. After cooling until the room temperature, the digested sample solution was made up to 50 ml with mercury-free water. The measurement of mercury in sample solution was carried out like method above.

Total mercury analysis in urine samples: For urine samples, add 2 ml conc.HNO_3-$HClO_4$ (1:1) and 5ml conc. H_2SO_4 to sample digestion flask beforehand. Gradually add a 5ml of urine sample while stirring slowly and heat at 200^o C on a hotplate for 30 min. After cooling until the room temperature, the digested sample solution was made up to 50 ml with mercury-free water. The measurement of mercury in sample solution was carried out like method above.

Accuracy of method was assessed with certified reference material NIES, No13 - Human hair (National Institute for Environmental Studies, Environment Agency, Japan). A recovery of Hg is 98.65%.

Hair sample

- Washed with neutral detergent and water
- Washed with acetone
- Dried under reduced pressure
- Cut finely with scissors in a 20ml counting vial

Hair sample, 10-20mg

- $H_2$0, 1ml
- Conc.HNO_3-$HClO_4$(1:1), 2ml
- Conc. H_2SO_4, 5ml
- Heated at 200^{o}C for 30 min

Digested sample

- Cooled down to room temperature
- Made up to 50 ml with water

Sample solution

- 10% $SnCl_2$ in 1N HCl, 0.5ml

Hg vapour

AAS

Fig1. Analytical procedure for T-Hg in hair sample

Blood sample, 500mg or less

- $H_2$0, 1ml
- Conc.HNO_3-$HClO_4$(1:1), 2ml
- Conc. H_2SO_4, 5ml
- Heated at 200^{o}C for 30 min

Digested sample

- Cooled down to room temperature
- Made up to 50 ml with water

Sample solution

- 10% $SnCl_2$ in 1N HCl, 0.5ml

Hg vapour

AAS

Fig2. Analytical procedure for T-Hg in blood sample

Result and discussion

Health assessment: The health status of 149 battery workers was assessed using the GMP's environmental and health assessment protocols (global mercury pollution) [8]. Medical questionnaires were given to workers. The workers were examined to assess their general health conditions as well as the possibility of mercury poisoning. . The results are shows in table 1:

Table1: Clinical examination for workers in battery

Symptoms	Percentage
Trembling	7.2%
Headache	12.8%
Numbness of extremities	1.9%
Decrease of tendon reflex	8.1%
Neurasthenia	7.2%
Proteinuria (>300mg/24h)	62%

The source of mercury pollution from battery production was summarized as below. The container of the battery, which also serves as one of the electrodes, is made of zinc. The container is lined with porous paper bag which separates the metal from the materials within the cell. A carbon (graphite) rod is placed at the center and used as the other electrode. The space between the carbon rod and the zinc container is filled with a moist mixture of ammonium chloride, manganese dioxide, zinc chloride, carbon powder and mercury as chloride. a mercury was added to activate zinc, normally content of mercury in battery is about 0.2-1%

Proteinuria is a condition in which urine contains an abnormal amount of protein. Normally, protein should not be detected in the urine. Proteinuria is a well-known symptom of an Hg-related effect in the kydneys. The clinical examination indicated that 62% of the workers had protein in urine so the function of kidney was damaged.

Concentration of mercury in hair, RBCs, plasma and urine from battery workers:

The concentrations of mercury in hair, RBCs, plasma and urine samples are shown in table 2. Urine and plasma T-Hg concentration are known as good biomarker of mercury vapour or divalent mercury exposure. The mean of T-Hg concentration in urine and plasma are generally expected to be 23.54 and 38.09 ppb respectively. The highest mercury concentration in their urine and plasma reached 51.20 and 31.24 ppb respectively. This Hg level in urine and plasma is about 5 times higher than the health-based occupational expose limit level (7 ppb) recommended by WHO [7]. The T-Hg content hair is not high but the T-Hg in RBCs in higher than the limit level (15 ppb) recommended by WHO. Base on results of T-Hg analysis in urine, plasma, RBCs and hair from workers in battery plants. The relationship between T-Hg in urine and Plasma was investigated; the T-Hg in plasma was significantly correlated with T-Hg in urine. This correlation can be explained that: The speciation of mercury in plasma and urine was mostly in form of inorganic.

Table 2: Concentration of T-Hg in urine, plasma, RBCs and hair

Samples		Gold miner			Workers in battery plants	
	Mean	Max	Min	Mean	Max	Min
Urine (ppb)	24.56	36.21	19.80	38.09	51.20	27.34
Plasma (ppb)	8.36	12.00	6.80	23.54	31.24	15.26
RBCs (ppb)	30.55	38.06	28.10	31.22	34.72	26.91
Hair (ppm)	8.04	16.65	4.28	2.51	4.56	1.18

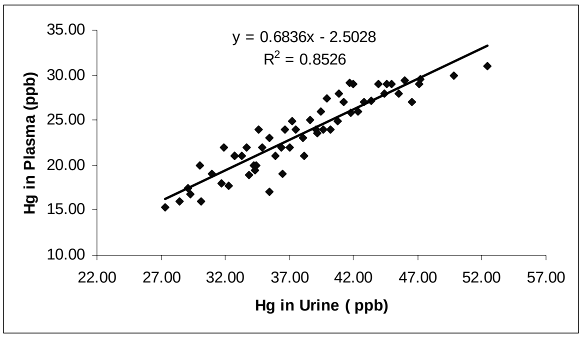

Fig 3: The correlation between T-Hg in urine and plasma from battery worker

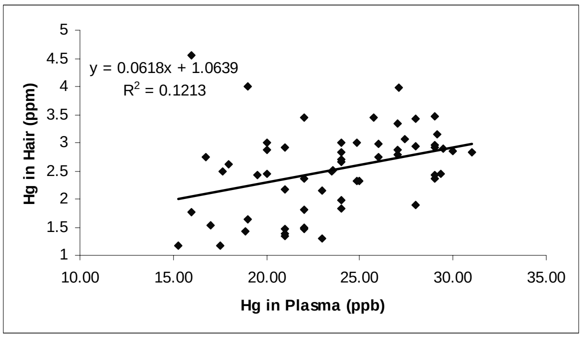

Fig 4: The correlation between T-Hg in urine and plasma from battery worker

Concentration of mercury in hair, RBCs, plasma and urine from gold miner:

The concentration of T-Hg content in RBCs and hair from gold miners is higher than that from workers in battery plants with the good significant correlation between T-Hg in hair and RBCs, in which most of the T-Hg in hair was in the methylated form and the ratio of T-Hg and MeHg was very close to 1(H. Akagi at al, 1995). The distribution of mercury between RBCs and hair is well known among people exposed to MeHg, while there was no relationship between T-Hg content in RBCs and urine and between urine and plasma

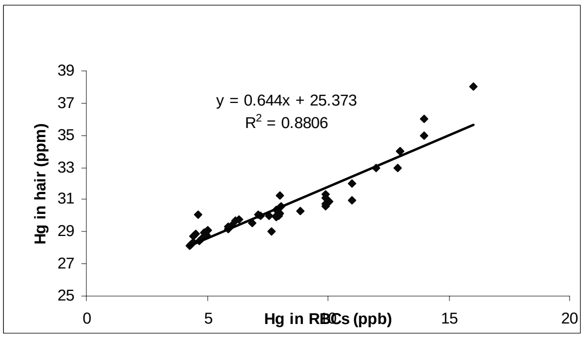

Fig 5: The correlation between T-Hg in hair and RBCs from gold miner

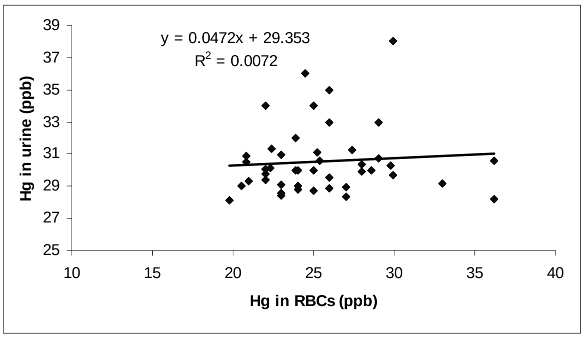

Fig 6: The correlation between T-Hg in urine and RBCs from gold miner

The results of T-Hg in hair and RBCs from Miner indicate that the gold miners are not only exposed to inorganic mercury but also methyl mercury through the food consumption. The T-Hg in fish and shellfish consumption for gold miner was investigated; the T-Hg content in fish and shellfish is ranged from 0.02 to 0.08 and from 0.07 to 0.38 ppm respectively

Conclusion

The accuracy of method was assessed with certified reference material NIES, No13 - Human hair (National Institute for Environmental Studies, Environment Agency, Japan). A recovery of Hg is 98.65%.

The current situation of mercury pollution and the resulting effects on the battery workers and gold miners have been clarified in the present study. The result to date has confirmed that mercury concentration in hair, RBCs, plasma and urine, was higher than the limit level recommended by WHO. The correlation between concentration of T-Hg in hair and RBCs from gold miner and between urine and plasma from battery workers was found. The results also indicated that Battery workers have been exposed by inorganic Hg and gold miners have been exposed by both inorganic and methyl Hg. The T-Hg content in urine and plasma is a highly potential biomarker for inorganic Hg exposure and Hg content in hair, blood (RBCs), and urine must be assessed for overall Hg exposure.

Acknowledgements

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Current Mercury Level in Cambodia -with Issue on Waste Management-

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Abstract

Kingdom of Cambodia has developed the economy since 1990's after the civil war and been trying to overcome "a country under a poverty threshold (1 USD a day)". However, its peaceful way is arduous and takes high priority to develop economy. As this result, many environmental problems surface as one of the critical issues in the country. In this situation, the illegal transboundary movement of hazardous waste containing mercury was happened in 1998. This was the most infamous incident of waste management issue but made all stakeholders open eye to think about strengthening appropriate measures against environmental issues. Ministry of the Environment, Kingdom of Cambodia, implements many activities to tackle various environmental issues supported by international organizations.

The samples were collected: 210 hair samples (60 samples at the city area and 27 samples at the open dumping sites in Phnom Penh; 43 samples in the city area and 80 samples in 2 fishing villages in Siem Reap), and 66 species of fish and seafood (22 species in Mekong and Tonle Sap river area; 41 species in Tonle Sap; 26 species in Sihanoukville on Gulf of Thailand. Of those samples, 21 species were common between Phnom Penh and Siem Reap, and 1 species was common between Siem Reap and Sihanoukville). The means of T-Hg in hair samples were: 2.70 μg·THg/g (all samples); 2.63 μg·THg/g (all male samples); 2.76 μg·THg/g (all female samples). The mean T-Hg in one fishing village was the highest among other sampling points as follows: 3.42 μg·THg/g (all samples); 3.56 μg·THg/g (male samples); 3.32 μg·THg/g (female samples). The mean T-Hg in fish and seafood samples were: 0.1062 μg·THg/g (Phnom Penh), 0.1056 μg·THg/g (Siem Reap); 0.1218 μg·THg/g (Sihanoukville).

As one of the poverty-driven activities, many people work at open dumping sites to collect plastics which make them earn small money. However, they do not care about their working condition which is absolutely messy and unsafe for their health. In addition, electric and electronic waste (E-waste) containing hazardous chemicals, such as mercury, are also dumped to the landfill sites, and hazardous chemicals are suspected to leak from the sites to the environment.

Keywords: Mercury, Cambodia, Tonle Sap, Sihanoukville, Hazardous wastes

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1. Introduction

The Asian region is recognised not only as the important area to produce a lot of daily products, "the factory of the world", but also as the contributor to the adverse effect to the environment and human health, due to a lot of the environmentally unfriendly activities. Most of the Asian countries take a high priority to develop the economy with small awareness of the environmental concerns, in order to obtain better life level. In addition, it is said that many past cases of the environmental pollution are related to poor-driven activities due to no opportunity to know that a traditional activity causes a serious damage to the environment.

The Kingdom of Cambodia is a country in Southeast Asia with a population of more than 13 million [1]. Cambodia had been the undeveloped country due to the wars and conflicts internationally and nationally[1.] After the comprehensive peace settlement in 1991[2], there are many economic and industrial activities to escape from poverty. In addition, Cambodia is recognised as one of the poorest countries in the world, and authorities concerned, especially public sectors, take high priority to develop economy[3].

Cambodia now faces many environmental issues, such as water pollution, land contamination, etc, due to the high priority to develop its economy on the environmentally unsound way[4]. It is said that those environmental issues are toward serious situation year by year[4]. Almost all people in Cambodia do not care about environmental concerns despite the fact that they might be caused by the adverse effects[5]. This situation is similar to the heavily environmental pollution in 1950's and 1960's in Japan. However, there are very limited activities on the environmentally sound manners in Cambodia[6]. Therefore, it can be imagine that the environment in Cambodia would be getting worse situation.

Mercury in Cambodia is also one of the urgent environmental issues, because Cambodia is recognised as one of the countries with references on the artisanal and small scale gold mining[7]. In addition, one of the main food sources for Cambodian is fish and seafood collected at Mekong river, Tonle Sap river, Tonle Sap lake, Gulf of Thai[8], which is also main source of mercury pollution because of the food chain[9]. Therefore, mercury pollution is suspected in Cambodia.

This study, "Current mercury level in Cambodia – with issues on waste management", aimed at identifying the current mercury level in not only human hair but also fish and seafood by collecting those samples in Cambodia. In addition, the issue on waste management, which is one of the urgent environmental issues, was discussed, taking into consideration the possibility of mercury pollution due to the environmentally unsound management for waste.

2. Materials and Methods

2.1 Field survey

The field survey had been conducted in Cambodia in August 2006 and was aimed at collecting not only the biological samples (hair, fish and seafood) but also information about mercury situation in Cambodia. The survey was conducted by the corroboration between National Institute for Minamata Disease, Ministry of the Environment, Japan, and Department of Pollution Control, Ministry of the Environment, Kingdom of Cambodia. The areas of the field survey were Phnom Penh as the capital area and the confluence of the Tonle Sap and Mekong rivers, Siem Reap and other villages facing to Tonle Sap as the local city and fishing villages and Sihanoukville as a port city on the Gulf of Thailand (Fig 1). The locations to have collected samples and its numbers were shown in Table 1. Of fish and seafood samples, twenty-one species were common between Phnom Penh and Siem Reap, and one species was common between Siem Reap and Sihanoukville.

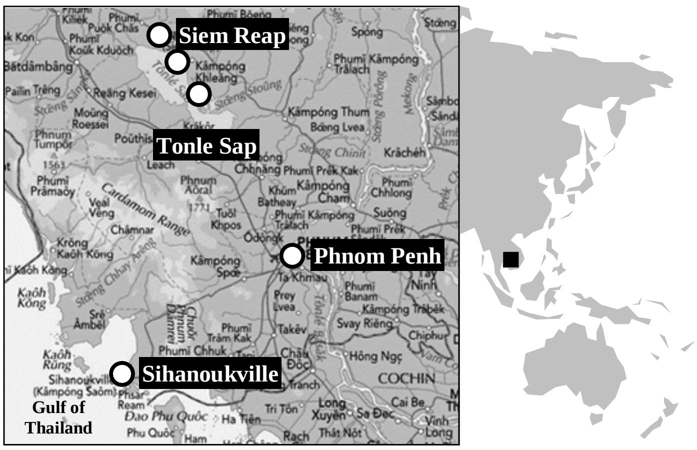

Fig 1 Locations of field survey

Table 1 Locations and numbers of sampling

	Hair samples	Fish and seafood samples
Phnom Penh	60 (City area) 27 (Landfill site)	22
Siem Reap	43 (City area) 43 (Fishing village 1) 37 (Fishing village 2)	41
Sihanoukville	-	26
Total	210	89

Hair samples were obtained from the occipital area of the head, cut 5-10 g from the hair root and stored in a polyethylene bag at room temperature[10]. Top 10[11] and other popular fish and seafood were bought at many fish markets (Table 2). Although, more than 1,200 fish species and 210 species have been identified in the Mekong River system and Tonle Sap River system[12], those top 10 and other fish and seafood collected by this study are represent of daily consumed fish and seafood, according to the several interviews at the fish and seafood markets. Whole fish or edible portion of fish and seafood samples were bought at the markets. An edible portion of whole fish was taken, and the edible portion of all samples were cut into fine pieces with knife, homogenized to a rough pasty state, preserved in the polyethylene case and stored in a freezer.

Table 2 List of the collected fish and seafood samples (No. of Top 10 popular fish)

City name	Name of fish and seafood samples (in Khmer)		
Phnom Penh (21 species)	Trey Riel (1)	Trey Chhdaur (2)	Trey Chhkok (3)
	Trey Khnawng Veng (4)	Trey Krum (5)	Trey Pruol (6)
	Trey Pra (7)	Trey Chhpin (8)	Trey Slak Russey (9)
	Trey Raws (10)	Trey Tilapia	Trey Khnontrop
	Trey Chlonh	Trey Donri	Trey Kronom
	Trey Chlath	Trey Groas	Trey Ondeng
	Trey Sanday	Trey Chkeng	Trey Krohei
	Trey Chling		
Siem Reap (41 species)	Trey Taorn	Trey Kés	Trey Lat
	Trey Kangchos	Trey Kompleang	Trey Praloung
	Trey Damrey	Trey Kanteousblok	Trey Kros Kanorngweng
	Trey Trasoksor	Trey Chareat	Trey Roloksor
	Trey Kaék	Trey Chalogn	Trey Kangtrongbreng
	Trey Kés	Trey Kapot	Trey Prama
	Trey Chab (Fresh water)		
Sihanoukville (26 species)	Ptoung Prat	Trey Beka	Bangkia Okaka
	Bangkia Pak	Bangkia Sos	Bangkia Soi
	Bangkia Kloeng	Klam Ses	Trey Kontoydomriy
	Trey Chek	Trey Thonsay	Trey Trosak
	Trey Kanthang	Trey Krohom	Trey Ondathchkei
	Trey Kpohaoug	Trey Krohomskakras	Trey Toeker
	Trey Bothtra	Trey Chab (Sea water)	Trey Baibel
	Trey Ptong	Trey Angrei	Chen Char
	Trey Chlam		

2.2 Method for mercury analysis

Total mercury (THg) concentration in the samples was determined by the wet digestion/reduction/cold vapour atomic absorption spectrometry (CVAAS: circulation-open air flow system)[10]. Hair samples were preliminarily washed with neutral detergent (diluted 100-fold) and distilled water by decantation, and wash again with little amount of acetone for removing water, then the residua acetone was removed under reduced pressure. Dried hair samples were cut into very small pieces by dissection scissors. Precisely weight of the sample (usually around 10 mg for hair samples and 0.5 g maximum of wet weight for fish and seafood samples) was taken into a 50 mL-sample digestion flask. One mL of distilled water, 2 mL of HNO_3-$HClO_4$ (1+1), and 5 mL of H_2SO_4 were added the flask. The flask was heated on a hot plate at 230°C for 30 minutes. After cooling down, the volume of digested samples was fixed at 50 mL with distilled water, mixed well and analyzed by CVAAS.

Methylmercury (MeHg) only in the fish and seafood samples whose total mercury concentrations were higher then 0.4 μg/g (Provisional regulatory standard for fish and shellfish, defined by Ministry of Health, Labour and Welfare, Japan[13]) was determined by the dithizone extraction/gas-liquid chromatography with electron capture detection (GLC-ECD) method[10]. Precisely weight of the samples (usually 0.2-0.5 g of wet weight) was taken and digested with 10 mL 1N KOH ethanol at 100°C for 1 hour. After cooling down, 10 mL 1N HCl and 5 mL hexane were added, shaken and centrifuged, and organic phase was removed. 2 mL 20% EDTA was added, 5 mL purified dithizone-toluene was added, shaken and centrifuged, and aqueous phase was removed. 3 mL 1N NaOH was added, shaken and centrifuged, and aqueous phase was removed (this process was repeated 2 times). After taking 4 mL organic phase, 2 mL alkaline sodium sulphide solution was added, shaken and centrifuged, and organic phase was removed. 2 mL toluene was added, shaken and centrifuged, and organic phase was removed. After adding 3-5 drops 1N HCl, the aqueous phase was aerated with N_2 gas at 50 mL/min for 3 minutes. After adding 2 mL Walpole's buffer, 0.5 mL purified ditizone-toluene was added, shaken and centrifuge, and aqueous phase was removed. 3 mL 1N NaOH was added, shaken and centrifuged, and aqueous phase was removed. After adding 2 drops 1N HCl, methylmercury was analyzed by GLC-ECD.

2.3 Statistical analyses

The pearson's correlation coefficient and the one-way ANOVA test using the SPSS 11 software programme were used to evaluate a relationship between THg concentration and age ($p < 0.05$) and significant difference (at $p < 0.05$) in terms of mercury concentrations of the hair samples, respectively. The paired Student's t-test was used to determine the relationship of 21 common species between Phnom Penh and Siem Reap, and Wilcoxon signed-rank test was used to identify any relationship of THg concentration in the fish and seafood samples among these 3 sampling areas.

3. Results

3.1 THg concentration in hair samples

Table 3 shows the THg concentration in the hair samples collected at the city area and landfill site in Phnom Penh, and the city are and 2 fishing villages in Siem Reap. The overall mean of THg in each sampling area was 2.51 ± 1.84 μg·THg/g at the city area and 2.06 ± 0.93 μg·THg/g at the landfill site in Phnom Penh, 2.46 ± 1.47 μg·THg/g at the city area, 3.01 ± 1.57 μg·THg/g at the fishing village 1 and 3.42 ± 1.41 μg·THg/g at the fishing village 2 in Siem Reap. THg mean concentrations between gender in each sampling area were 2.34 ± 1.24 μg·THg/g (Male: the city area in Phnom Penh), 2.72 ± 2.42 μg·THg/g (Female: the city area in Phnom Penh), 1.85 ± 0.75 μg·THg/g (Male: the landfill site in Phnom Penh) and 2.22 ± 1.04 μg·THg/g (Female: the landfill site in Phnom Penh), 2.59 ± 0.95 μg·THg/g (Male: the city area in Siem Reap) and 2.39 ± 1.71 μg·THg/g (Female: the city area in Siem Reap), 2.98 ± 0.71 μg·THg/g (Male: the fishing village 1 in Siem Reap) and 3.02 ± 1.86 μg·THg/g (Female: the fishing village in Siem Reap), and 3.56 ± 1.65 μg·THg/g (Male: the fishing village 2 in Siem Reap) and 3.32 ± 1.24 μg·THg/g (Female: the fishing village 2 in Siem Reap). The overall mean of all the samples was 2.70 ± 1.59 μg·THg/g

Table 3 THg concentration in the hair samples collected at Phnom Penh and Siem Reap

		Overall			Male			Female		
		No.	Age	THg (μg/g)	No.	Age	THg (μg/g)	No.	Age	THg (μg/g)
Phnom Penh	City area	60	29	2.51 ± 1.84 2.08*	34	28	2.34 ± 1.24 2.05*	26	30	2.72 ± 2.42 2.12*
					Child-bearing age			17	32	3.22 ± 2.84 2.43*
	Landfill site	27	30	2.06 ± 0.93 1.89*	12	22	1.85 ± 0.75 1.73*	15	36	2.22 ± 1.04 2.03*
					Child-bearing age			9	31	2.50 ± 1.03 2.34*
Siem Reap	City area	43	23	2.46 ± 1.47 2.42*	16	21	2.59 ± 0.95 2.42*	27	24	2.39 ± 1.71 2.00*
					Child-bearing age			17	23	2.63 ± 2.04 2.13*
	Fishing village 1	43	24	3.01 ± 1.57 2.96*	14	33	2.98 ± 0.71 2.90*	29	19	3.02 ± 1.86 2.64*
					Child-bearing age			12	24	3.88 ± 2.49 3.28*
	Fishing village 2	37	28	3.42 ± 1.41 2.96*	16	24	3.56 ± 1.65 3.20*	21	30	3.32 ± 1.24 3.03*
					Child-bearing age			15	28	3.52 ± 1.03 3.36*
Overall		210	26	2.70 ± 1.59 2.34*	92	26	2.63 ± 1.26 2.35*	118	27	2.76 ± 1.81 2.34*
					Child-bearing age			70	28	3.16 ± 2.10 2.64*

*: Geometric mean

(all samples), 2.63 ± 1.26 μg·THg/g (Male) and 2.76 ± 1.81 μg·THg/g (Female). The maximum THg was 3.56 μg·THg/g for the male samples collected at the fishing village 2.

THg concentrations of women who is a child-bearing age (15-45) were 3.22 ± 2.84 μg·THg/g at the city area and 2.50 ± 1.03 μg·THg/g in Phnom Penh, 2.63 ± 2.04 μg·THg/g at the city area, 3.88 ±2.49 at the fishing village 1 and 3.52 ± 1.03 μg·THg/g at the fishing village 2 in Siem Reap, and 3.16 ±2.10 μg·THg/g as the overall mean.

The statistical analysis on THg data by Pearson's correlation coefficient showed that there was no statistical relationship between THg concentration and age on genders in each sampling area. This meant that the one-way ANOVA test was not available for further statistical analysis.

3.2 THg and MeHg in fish and seafood samples

Figure 3 shows the T-Hg concentration in fish and seafood samples collected at Phnom Penh, Siem Reap and Sihanoukville. 0.4 μg·THg/g, the provisional regulatory standard for fish and shellfish defined by Ministry of Health, Labour and Welfare, Japan[13], was quoted for considering THg level, due to no organizations in Cambodia have defined a provisional regulatory standard for fish and selfish yet. Taking into consideration the strictest THg level, 0.2 μg·THg/g, the maximum allowed THg concentration in fish defined for people who consume large amount of fish defined by Canada, was also quoted[9]. Of total 88 species, only 2 species, Trey Angrei and Trey Taorn, exceeded 0.4 μg·THg/g. The samples which exceeded 0.2 μg·THg/g were Trey Chiling, Trey

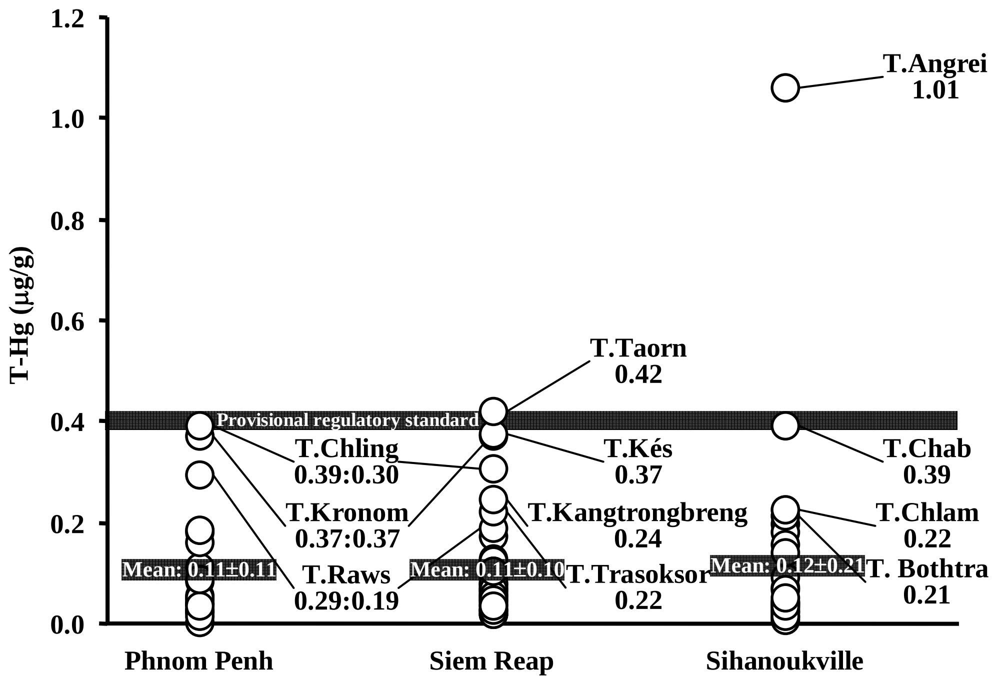

Fig 3 THg concentration in fish and seafood samples. T: Trey. THg conc (Phnom Penh):THg conc (Siem Reap). Provisional regulatory standard for fish and shellfish (Ministry of Health, Labour and Welfare, Japan): 0.4 μg·THg/g [13]

Kronom, Trey Raws (the sample in Phnom Penh only), Trey Kés, Trey Kangtrongbreng, Trey Trasoksor, Trey Chab, Trey Chlam and Trey Bothtra. 59 samples were less than 0.1 μg·THg/g. The means of THg in Phnom Penh, Siem Reap and Sihanoukville were 0.1062 ± 0.1150, 0.1056 ± 0.1026 and 0.1218 ± 0.2159 μg·THg/g, respectively. The overall mean was 0.1105 ± 0.1442 μg·THg/g.

Table 4 shows the THg and MeHg concentrations and its percentage (MeHg/THg) in the samples which exceeded 0.2 μg·THg/g. It was confirmed that almost all THg in the samples was MeHg. Of the samples whose THg concentration was between 0.2 and 0.4 μg·THg/g, MeHg concentration of Trey Kronom, Trey Chling, Trey Kés and Trey Chab (sea water) exceeded 0.3 μg·MeHg/g which is the provisional regulatory standard as MeHg for fish and shellfish[13]. Methylmercury content was around 97% of the total mercury.

The paired Student's t-test analyzed that there was the significance ($p < 0.001$, $r = 0.938$) between the 21 common fish and seafood samples collected in Phnom Penh and Siem Reap. However, no further statistical significance and relationship was obtained.

Table 4 THg and MeHg concentration in the samples which exceeded 0.2 μg·THg/g

	City*	THg (μg/g)	MeHg (μg/g)	THg/MeHg (%)
Trey Raws	PP	0.2902 ± 0.0096	0.2831 ± 0.0094	97.54
	SR	0.1880 ± 0.0054	0.1795 ± 0.0094	95.48
Trey Kronom	PP	0.3691 ± 0.0049	0.3611 ± 0.0051	97.84
	SR	0.3742 ± 0.0044	0.3695 ± 0.0051	98.74
Trey Chling	PP	0.3875 ± 0.0144	0.3791 ± 0.0085	97.84
	SR	0.3057 ± 0.0087	0.2914 ± 0.0085	95.32
Trey Taorn	SR	0.4173 ± 0.0084	0.4093 ± 0.0071	98.07
Trey Trasoksor	SR	0.2178 ± 0.0092	0.2104 ± 0.0043	96.62
Trey Kangtrongbreng	SR	0.2433 ± 0.0079	0.2391 ± 0.0095	98.27
Trey Kés	SR	0.3707 ± 0.0184	0.3605 ± 0.0084	97.25
Trey Bothtra	SV	0.2124 ± 0.0083	0.2054 ± 0.0046	97.69
Trey Angrei	SV	1.0565 ± 0.0515	1.0231 ± 0.0412	96.84
Trey Chab (sea water)	SV	0.3907 ± 0.0058	0.3811 ± 0.0091	97.54
Trey Chlam	SV	0.2222 ± 0.0182	0.2151 ± 0.0103	96.79

* PP: Phnom Penh; SR: Siem Reap; SV: Sihanoukville

4. Discussion

4.1 Mercury level in Cambodia

This study could collect 210 hair samples and 89 fish and seafood samples in Phnom Penh as the capital are and the confluence of the Tonle Sap and Mekong rivers, Siem Reap and its neighbouring villages as the local city and fishing villages, and Sihanoukville as the port city on the Gulf of Thailand. The overall mean concentration of THg in the hair samples was 2.70 ± 0.11 μg·THg/g (both genders), 2.63 ± 0.13 μg·THg/g (male) and 2.76 ± 0.17 μg·THg/g (female). The geometric mean of these concentrations were 2.34 μg·THg/g (both genders), 2.35 μg·THg/g (male) and 2.34 μg·THg/g (female). The overall geometric mean of THg for the male samples in Cambodia was lower than that (2.47 μg·THg/g) of Japan, however, its mean for female samples in Cambodia was higher than that (1.65 μg·THg/g) of Japan[14]. These geometric means of THg in Cambodia exceed the provisional tolerable weekly intake (PTWI) level (1.6 μg·THg/kg·BW/week), corresponding to about 2.2 μg·THg/g·hair) determined at the 61st meeting of the Joint FAO/WHO Expert Committee on Food Addictives (JECFA)[15].

The THg geometric means on women of child-bearing age, except in the fishing village 1, exceeded PTWI as 2.2 μg·THg/g, and these THg concentrations are much less than the threshold of the fetal lowest-effect level at 12 μg·THg/g·maternal hair. It is the safety level which does not mean any mercury pollution at this moment. Unfortunately, there is no guideline for mercury, such as PTWI, a tolerant weekly intake (TWI) of mercury from food consumption in Cambodia. If Cambodian authorities concerned on mercury issues, such as Ministry of the Environment, the Council for Agricultural and Rural Development, etc, define PTWI for fish and seafood consumption against mercury, its should be involved the national and geographical factors and food consumption pattern and expected to be bit higher than that of JECFA.

Of the fish and seafood samples, only 2 species exceeded 0.4 μg·THg/g which is the provisional regulatory standard for fish and shellfish defined by Ministry of Health, Labour and Welfare, Japan[12], and 9 species exceeded 0.2 μg·THg/g which is the maximum allowed THg concentration in fish defined for people who consume large amount of fish, Canada[9]. These samples are not popular fish and seafood for Cambodia people, except Trey Raws (0.29 μg·THg/g in Phnom Penh and 0.19 μg·THg/g in Siem Reap) which is the 10th popular fish as a daily food in Cambodia[11]. This means that mercury level in daily fish and seafood in Cambodia is not high level. However, a suspect problem on mercury pollution due to fish and seafood consumption is large amount (75.6 kg/capita/year) of fish and seafood consumption by the fishing dependent communes[16]. This amount is the largest in the Asian countries (Republic of Korea: 68 kg/capita/year; Taiwan: 60 kg/capita/year;and Hong Kong: 58 kg/capita/year)[17]. Therefore, it is important to consider how many fish and seafood Cambodia people consume yearly, despite the fact that THg concentrations in fish and seafood in Cambodia are less than any standards.

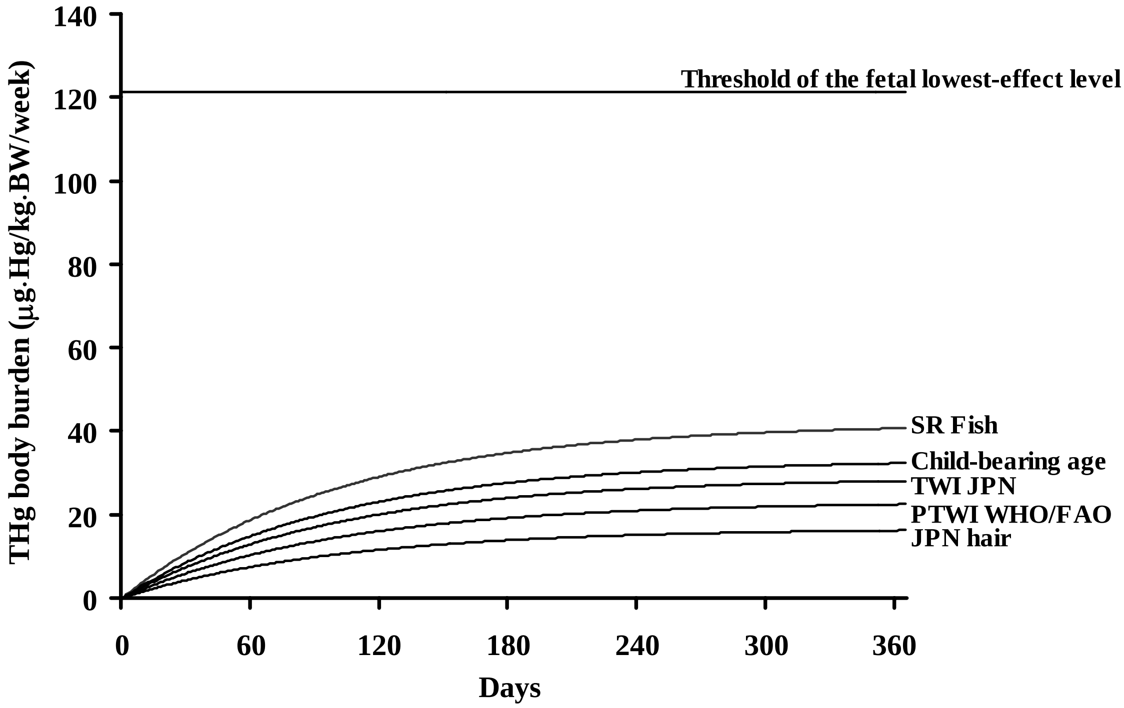

Fig.4 Estimation of THg body burden. SR Fish: 2.9 µg·THg/kg·BW/week (0.1056 µg·THg/g (the geometric mean of fish and seafood samples in Siem Reap) × (75.6 kg·fish/capita/365 days[16] × 7 days)); Child-bearing age: 2.23 µg·THg/kg·BW/week (0.328 µg·THg exposure (the fishing village 1)/kg·BW/day × 7 days), if 1 ng·THg/mg·Hair = 0.1 µg·THg exposure/kg·BW/day); TWI JPN: 2.0 µg·THg/kg·BW/week[13]; PTWI WHO/FAO: 1.6 µg·THg/kg·BW/week[15]; JPN hair: 1.15 µg·THg/kg·BW/week (0.165 µg·THg exposure/kg·BW/day[14] × 7 days), if 1 ng·THg/mg·Hair = 0.1 µg·THg exposure/kg·BW/day)

Figure 4 shows the estimation of THg body burden. The following THg data was quoted: 0.1056 µg·THg/g (the geometric mean of fish and seafood samples in Siem Reap), Child-bearing age: 2.23 µg·THg/kg·BW/week (0.328 µg·THg exposure/kg·BW/day × 7 days), if 1 ng·THg/mg·Hair = 0.1 µg·THg exposure/kg·BW/day). The threshold of the fetal lowest-effect level, TWI in Japan and PTWI WHO/FAO were used as the references for comparisons. The THg body burden calculated from the largest THg concentration in the hair samples on women of a child-bearing age in the fishing village 1 exceeded TWI JPN and PTWI WHO/FAO. Although its body burden is much less than that of the threshold of the fetal lowest-effect level, THg body burden in women of a child-bearing age in Cambodia means a necessary to take an appropriate activity on mercury issues in Cambodia, such as issue of guidelines, assessment, etc.

This study focused on only hair samples at the control areas (the city areas in Phnom Penh and Siem Reap) and the areas where mercury pollution is suspected (the landfill site) and whose people eat a lot of fish and seafood (the fishing villages). In Cambodia, there are other areas where mercury pollution is suspected, such as an artisanal and small scale gold mining areas, small workshops dealing with electric and electronic waste, etc.

4.2 Waste management issues in Cambodia, as an urgent environmental issue

In November 1998, the infamous event, the illegal transboundary movement of hazardous waste containing mercury, was happened [18]. The hazardous waste was imported from Taiwan to Sihanoukville, Cambodia. Before the event, the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was entry into force in 1992[19]. However, unfortunately, Taiwan was not politically the party to the Basel Convention and Cambodia was not the party to the Basel Convention. Although the transboundary movement of the event was dealt with no legal agreement between both countries and the private sectors dealt with all transactions, this event made a lot of the adverse effects to human health and the environment[18]. One of the actions by local people was to steal the plastic bags encasing hazardous waste containing mercury, because local people or scavengers could make money to sell plastic bags to dealers as their income. However, this action made those persons directly contact with hazardous waste containing mercury, and eventually most of them complained about somatise, dizziness, weakness, visual trouble, headache, etc[18]. Despite this event, a lot of local people and scavengers deal with plastic bags and other reusable/recyclable wastes throughout Cambodia as an informal sector on the environmentally unsound way which causes the adverse effect to their health and the environment. This is one of the major poverty-driven activities in not only Cambodia but also other developing countries.

Ministry of the Environment, Cambodia, became to the party to the Basel Convention in 2001 and has undertaken many projects on waste management with international organisations since then. Although the mechanism and capacity for waste management have been improving, there are many suspected concerns about environmental pollution due to complication of waste management issues with high priority to develop economy. Hg pollution seems not to surface as a current environmental problem at all according to the result of this study. However, Cambodia faces many environmental concerns relating to Hg, such as E-waste[20], lead-acid batteries[21], management for health care waste, etc which might cause a serious environmental pollution in future, and has not been able to fully take environmentally sound management yet.

The national capacity for environmental management should be raised as the most important activity to tackle not only waste management issue with the issue on mercury pollution. Although the governmental and other sectors have many activities on various environmental problems, an appropriate activity or research work on mercury issues (with waste management issue) seems to be very limited in Cambodia. In order to undertake an appropriate activity for the environmental problems, cooperation on environmental project among all stakeholders should be strengthen effectively, international organizations or institutes should provide knowledge and expertise with techniques and technologies on the environmentally sound management.

5. Conclusion

This study, Current mercury level in Cambodia – with issue on waste management, focused on the field survey on mercury level in hair samples at the city area and landfill site in Phnom Penh, at the city area and 2 fishing villages in Siem Reap, and fish and seafood samples collected at Phnom Penh, Siem Reap and Sihanoukville. The geometric THg means in the hair samples were 2.34 μg·THg/g for the overall samples, 2.35 μg·THg/g for the overall male samples and 2.34 μg·THg/g for the overall female samples. The geometric THg means in the hair samples on women of a child-bearing age were 2.43 μg·THg/g at the city area and 2.34 μg·THg/g at the landfill site in Phnom Penh, 2.13 μg·THg/g at the city area, 3.28 μg·THg/g at the fishing village 1 and 3.26 μg·THg/g at thee fishing village 2 in Siem Reap, and 2.64 μg·THg/g as the overall mean. These THg means, except THg at the city area in Siem Reap, exceeded PTWI WHO/FAO. Only two fish and seafood samples exceeded the provisional regulatory standard for fish and shellfish defined by the Ministry of Health, Labour and Welfare, Japan. Although there is no guidelines and standard in terms of mercury in Cambodia, the mercury level is slightly higher than the international standard for the concerns on the adverse effects to human health though consumption of fish and seafood. In addition, there are many environmental issues in Cambodia, such as municipal solid waste, E-waste, health care waste, batteries, etc, which might link to mercury issues. Therefore, a comprehensive research approach for the environmental issue should be undertaken by all stakeholders, such as national authorities, international organizations and institutes, private sectors and local communities.

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Mercury Pollution Issue in Buyat Bay, Minahasa, Indonesia

Dr. Supriyanto Margono

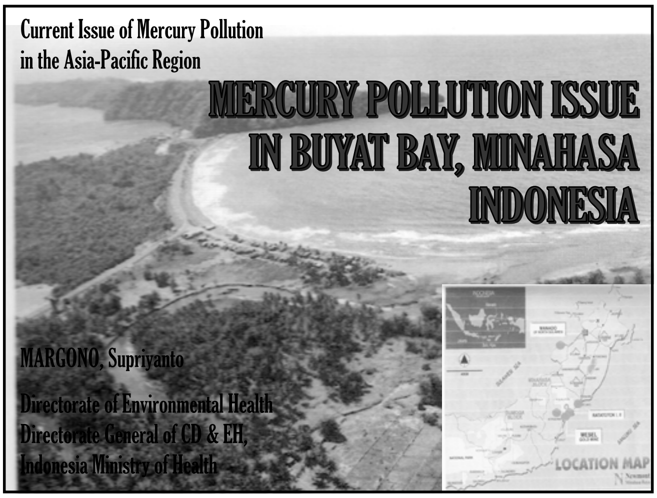
Ministry of Health, Indonesia

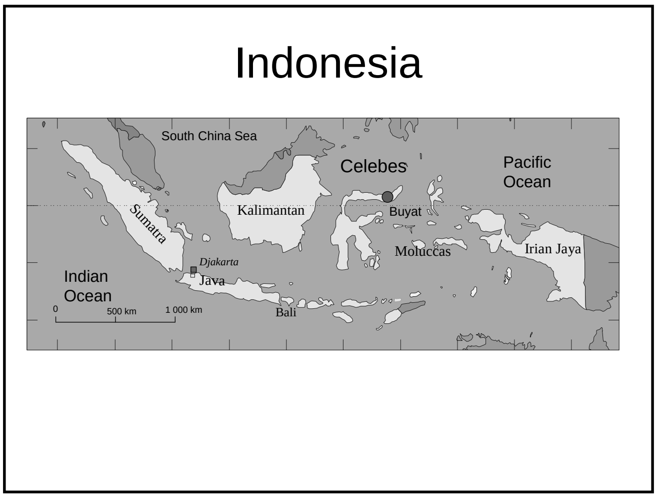
In July 2004, mercury pollution issue was appeared in Minahasa, North Sulawesi, Indonesia. They are two types of gold mining, namely traditional and modern one. The traditional gold mining consists of 493 units, spread of 28 locations in 13 sub districts. The modern gold mining is located in Buyat Ratatotok, started in 1994, but it had already finished.

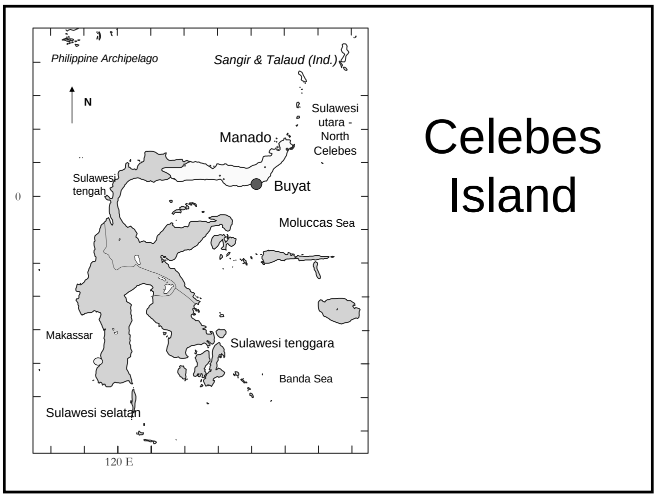
The result of research to the fishes describe as follows:

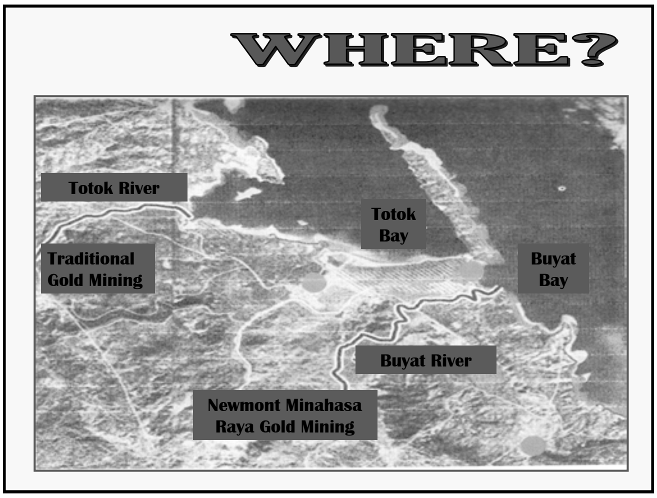
- Inorganic mercury within fishes in Buyat Bay was still under the requirement level.
- Mercury compound within fishes in Buyat Bay case was less than the Minamata case, the result of Minamata Institute and WHO research were similar.
- Dissolved mercury compound in Totok and Buyat Bays were similar. Most of them were under the detection method limit and also under the level of requirement.

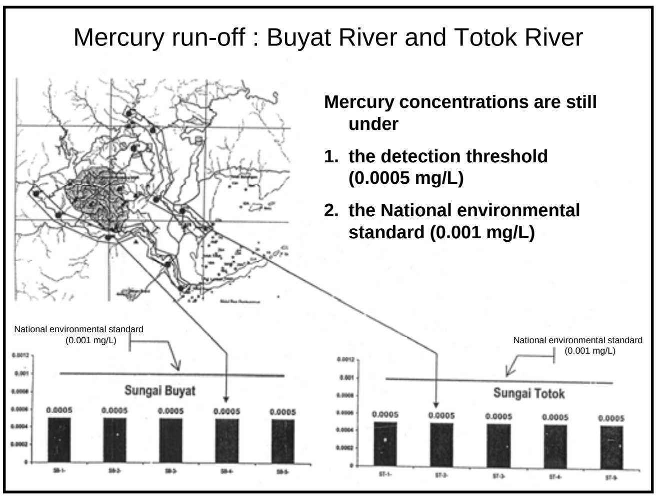
The compounds of mercury examined to the blood and hair were under the tolerable level for the community lived in the beach (WHO/IPCS). In the case areas, the median of mercury compound was 7.42 micrograms per liter in blood and 2.29 micrograms per gram in hair. In the control area, the median of mercury compound were 6.49 microgram per liter in blood and 2.18 microgram per gram in hair.

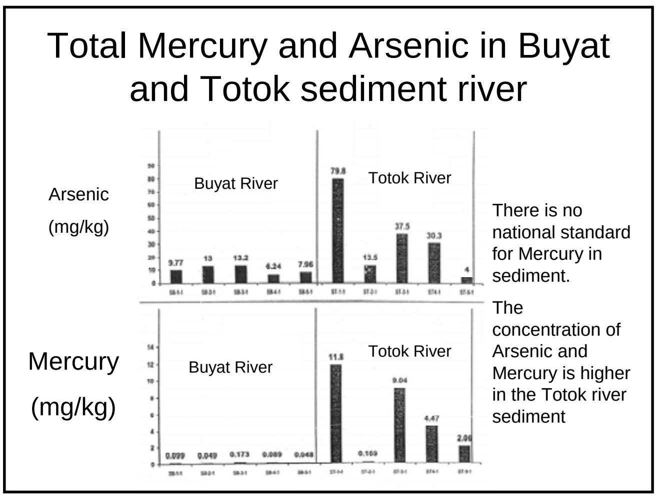

Current Issue of Mercury Pollution
in the Asia-Pacific Region
MERCURY POLLUTION ISSUE
IN BUYAT BAY, MINAHASA
INDONESIA
MARGONO, Supriyanto
Directorate of Environmental Health
Directorate General of CD & EH,
Indonesia Ministry of Health
LOCATION MAP

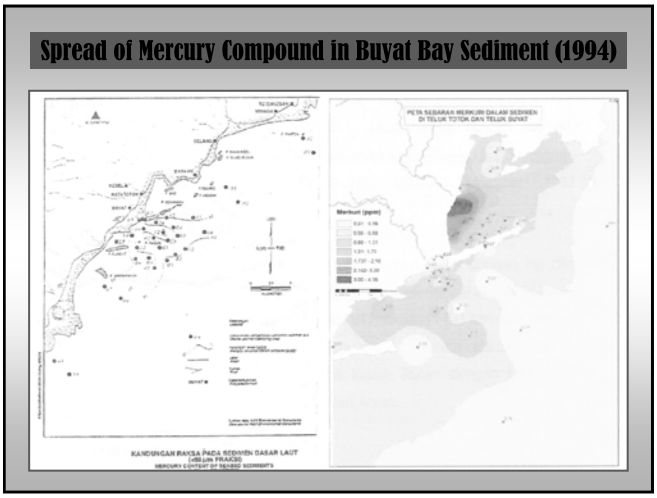

Indonesia
South China Sea
Celebes
Pacific
Ocean
Kalimantan
Buyat
Sumatra
Moluccas
Irian Jaya
Djakarta
Java
Indian
Ocean
0
500 km
1 000 km
Bali

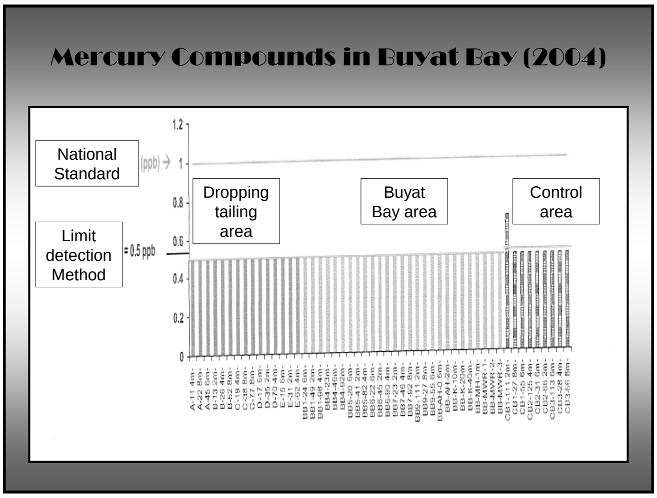

Philippine Archipelago
Sangir & Talaud (Ind.)
N
Sulawesi
utara -
North
Celebes
Manado
Sulawesi
tengah
Buyat
Moluccas Sea
Makassar
Sulawesi tenggara
Banda Sea
Sulawesi selatan
120 E
Celebes
Island

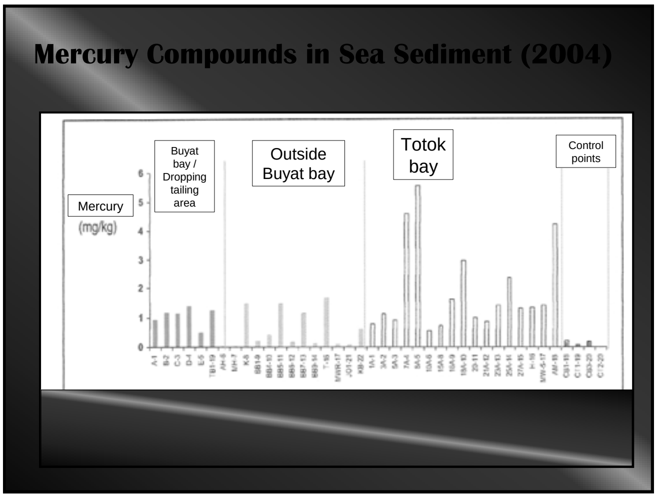

WHERE?
Totok River
Totok
Bay
Traditional
Gold Mining
Buyat
Bay
Buyat River
Newmont Minahasa
Raya Gold Mining

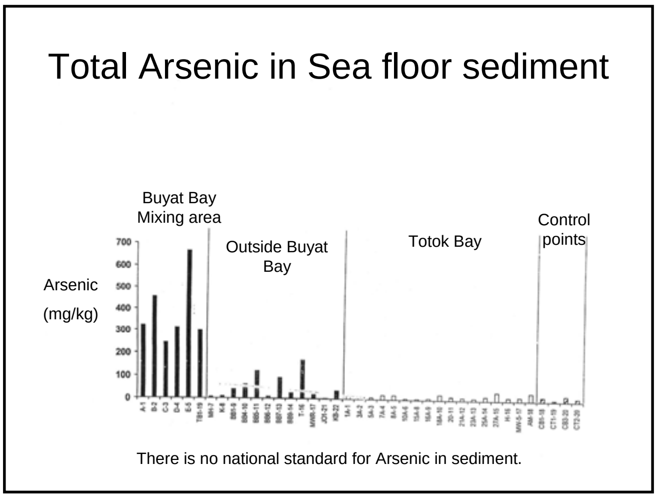

Mercury run-off : Buyat River and Totok River
Mercury concentrations are still under
1. the detection threshold (0.0005 mg/L)
2. the National environmental standard (0.001 mg/L)
National environmental standard
(0.001 mg/L)
Sungai Buyat
0.0005
0.0005
0.0005
0.0005
0.0005
National environmental standard
(0.001 mg/L)
Sungai Totok
0.0005
0.0005
0.0005
0.0005
0.0005

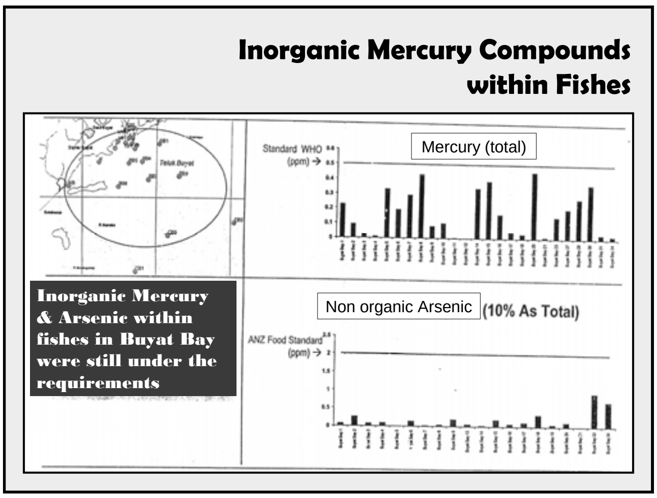

Total Mercury and Arsenic in Buyat
and Totok sediment river
Arsenic
(mg/kg)
Buyat River
Totok River
9.77
13
13.2
6.24
7.96
79.8
13.5
37.5
30.3
4
There is no national standard for Mercury in sediment.
The concentration of Arsenic and Mercury is higher in the Totok river sediment
Mercury
(mg/kg)
Buyat River
Totok River
0.099
0.049
0.173
0.089
0.048
11.8
0.169
9.04
4.47
2.06

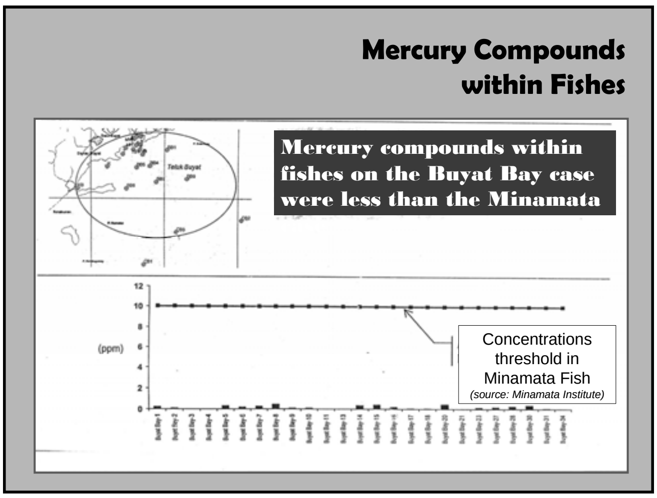

Spread of Mercury Compound in Buyat Bay Sediment (1994)
KANDUNGAN RAKSA PADA SEDIMEN DASAR LAUT
MERCURY CONTENT OF SEABED SEDIMENTS
PETA SEBARAN MERKURI DALAM SEDIMEN DI TELUK TOTOK DAN TELUK BUYAT

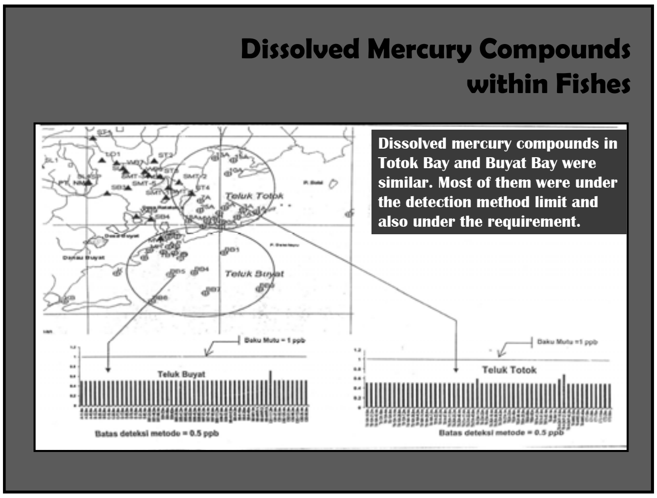

Mercury Compounds in Buyat Bay (2004)
National Standard
Limit detection Method
Dropping tailing area
Buyat Bay area
Control area
(ppb)
0.5 ppb

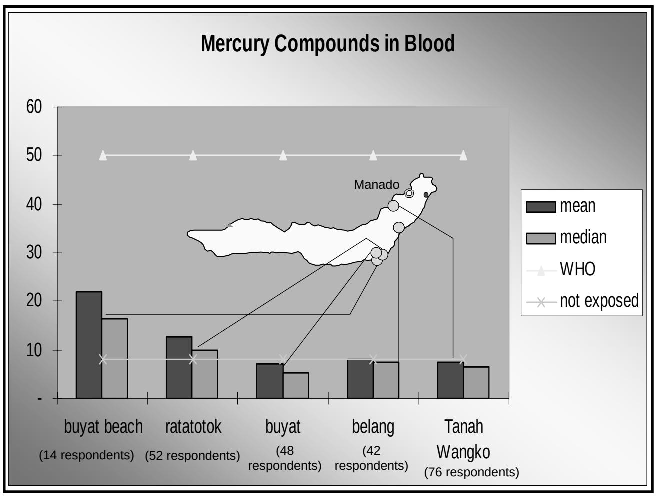

Mercury Compounds in Sea Sediment (2004)
Mercury
(mg/kg)
Buyat bay / Dropping tailing area
Outside Buyat bay
Totok bay
Control points

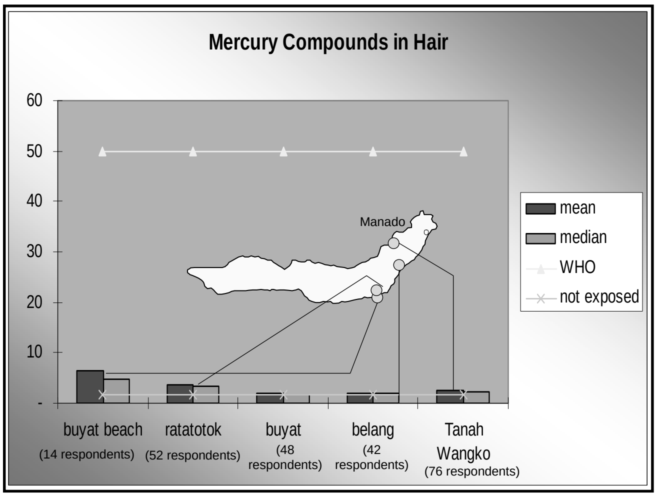

Total Arsenic in Sea floor sediment
Buyat Bay Mixing area
Outside Buyat Bay
Totok Bay
Control points
Arsenic
(mg/kg)
There is no national standard for Arsenic in sediment.


Inorganic Mercury Compounds within Fishes
Mercury (total)
Standard WHO (ppm)
Non organic Arsenic
(10% As Total)
ANZ Food Standard (ppm)
Inorganic Mercury & Arsenic within fishes in Buyat Bay were still under the requirements

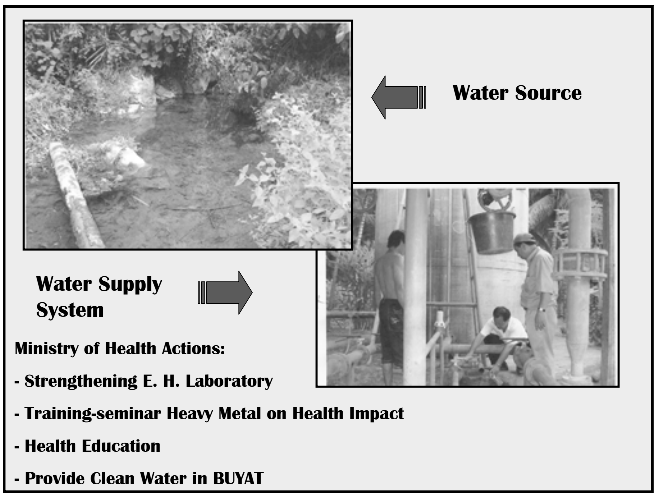

Mercury Compounds within Fishes
Mercury compounds within fishes on the Buyat Bay case were less than the Minamata
(ppm)
Concentrations threshold in Minamata Fish
(source: Minamata Institute)


Dissolved Mercury Compounds within Fishes
Dissolved mercury compounds in Totok Bay and Buyat Bay were similar. Most of them were under the detection method limit and also under the requirement.
Teluk Totok
Teluk Buyat
Baku Mutu = 1 ppb
Batas deteksi metode = 0.5 ppb


Mercury Compounds in Blood
60
50
40
30
20
10
-
Manado
mean
median
WHO
not exposed
buyat beach (14 respondents)
ratatotok (52 respondents)
buyat (48 respondents)
belang (42 respondents)
Tanah Wangko (76 respondents)


Mercury Compounds in Hair
60
50
40
30
20
10
-
Manado
mean
median
WHO
not exposed
buyat beach (14 respondents)
ratatotok (52 respondents)
buyat (48 respondents)
belang (42 respondents)
Tanah Wangko (76 respondents)


We eat fish everyday
We are happy


Water Source
Water Supply System
Ministry of Health Actions:
- Strengthening E. H. Laboratory
- Training-seminar Heavy Metal on Health Impact
- Health Education
- Provide Clean Water in BUYAT


THANK YOU

Mercury Vapor Exposure in Small Plants Manufacturing Mercury Thermometers

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Abstract

The relationship between the concentration of mercury in biological samples and the symptoms and signs of mercury poisoning in employees of small plants manufacturing mercury thermometers was investigated. The mercury concentration in the air of the thermometer factories showed higher values compared to chloralkali and chemical factories. Symptoms of mercury poisoning such as tremors, speech disorder, ataxia, irritability, and salivation were observed in the employees who had a high mercury concentration in blood and urine. When the mercury concentration exceed 300 μg/l in the urine or 100 ng/ml in the blood, an increase in the prevalence of tremors was observed. The total protein and β_2-microglobulin levels in the urine were also examined to clarify the disturbance of renal function caused by mercury vapor exposure. There was no significant correlation between the mercury concentration and total protein and β_2-microglobulin in the urine of employees. On the other hand, mercury levels in the urine and blood samples were significantly correlated with the levels of mercury exposure for each worker. A mercury exposure level of 0.1 mg/m^3 corresponds to a blood mercury level of 60 to 70 ng/ml and urinary mercury levels of 100 to 230 μg/l. A significant correlation was also found between the blood mercury and urinary mercury levels.

In a survey on the exposure levels of thermometer manufacturing workers to mercury vapor, a case of severe chronic mercury poisoning was found. The patient, a 54-year-old man, who carried out the refining of metallic mercury in his house, had typical symptoms of mercury intoxication as described above, and showed high levels of mercury in the blood (508 ng/ml) and urine (1910 μg/l). The mercury levels of blood and urine gradually decreased with medication and the symptoms of mercury intoxication gradually normalized. His wife also showed slight mercury poisoning. Furthermore, their child had a high blood concentration of 300 ng/ml, revealing the symptoms of mercury intoxication, severe mental retardation, and stomatitis.

In workers exposed repeatedly to mercury vapor exceeding the TLV (Threshold Limit Value) recommended by WHO, an increase in the prevalence of signs and symptoms of mercury intoxication was observed. Determination of the mercury concentration in the urine and blood also serves as a useful indicator for assessing the levels of exposure to mercury vapor. These facts indicate the importance of biological monitoring for mercury vapor exposure as a way to prevent chronic mercury poisoning. In addition, the findings of an infant case of mercury poisoning indicate that metallic mercury-handling work in a residence runs the risk of mercury exposure to the family.

Key Words: Mercury vapor, Poisoning, Blood, Urine, Exposure

Introduction

Chronic mercury poisoning has been observed among workers engaged in the manufacture of thermometers, mercury fluorescent lamps and the clinical thermometers, and those involved in the chloralkali industry and mercury mining in Japan after the Second World War. Recently, the reported cases of mercury poisoning have abruptly decreased as a result of improvements in the environment at elemental mercury-handing workshops and the closure of mercury mines. However, the working environments of small-scale mercury-handling factories, such as those involved in the manufacture of thermometers and the refining of mercury, in the 1980's were slow to improve, and consequently, a number of workers were exposed to high concentrations of mercury vapor.

It was reported that mercury levels in the air of work rooms in chloralkali plants correlated with prevalence of several medical findings (Smith et al., 1970). When mercury levels in air were over 0.1 mg/m^3, increases in the prevalence of symptoms such as loss of appetite, weight loss, object tremors and insomnia were observed. It is difficult to evaluate the actual status of mercury exposure at working sites in small-scale plants handling metallic mercury. The determination of mercury in urine or blood, as well as air concentration analysis, is known to play an important role in evaluating the extent of mercury exposure as well as the degree of risk (Simth et al., 1970; Lindstedt et al., 1979) The first report described the relation between the signs and symptoms and the level of exposure to mercury vapor of workers in small-scale thermometer factories.

In the survey on small-scale mercury thermometer factories, a case of severe chronic mercury poisoning was found in a mercury worker who had been refining mercury in his house. In this case, the work place was in close proximity to the family’s sleeping area; consequently the family members also suffered to mercury poisoning. Next, we described a case of chronic mercury poisoning and the clinical symptoms, and mercury levels in biological sample of his family.

Materials and Methods

In several factories manufacturing mercury thermometers, mainly scattered in the district of Tokyo, 27 male workers, aged 23-61 years and employed for 1-33 years, were studied.

Mercury in the work environment air was collected in an air bubbler containing a scrubbing solution of an acid-permanganate. The sampler was placed at a fixed location in the work area. The mercury collected in the sampler was measured by flameless atomic absorption. Individual exposure to mercury was estimated by a personal sampling technique (Yoshida et al., 1985). Mercury vapor was made by passing air through a glass tube containing gold wire, which was attached to the worker's collar in his breathing zone. The samples were collected continuously through the day work shift. After collection, the mercury was removed from the gold amalgam by thermal decomposition, absorbed in an acid-permanganate scrubber, and subsequently determined by flameless atomic absorption.

The inorganic mercury concentration of urine and blood was determined by the method of Magos (1971).

Case report

The patient, a 54-year-old man, had been engaged in washing mercury with diluted nitric acid at his home for 26 years. For the preceding six years, he had suffered by tremors in his hands, making it difficult for him to write. Tremors had also appeared in his lower extremities. He had symptoms of mercury intoxication such as psychic irritability, timidity, insomnia, uneasiness, depression, and amnesia for the preceding five years.

He had been troubled with visual hallucinations before falling asleep in bed for about two years. For example, he shouted that man-sized rats were running on the ceiling or getting into his bed. He also had a nightmare in which he was attacked by wild beasts. The tremor and ataxia had become so aggravated that he had been unable to sit up in bed for the preceding six months.

On admission, the patient was pale and emaciated. His teeth were in poor condition with many missing. Gingivitis with the characteristic blue-purple lines occurring on the upper and lower gums was observed (Figure 1). The patient had severely offensive breath. There was a coarse tremor of the arms both at rest and at attention, in addition to truncal tremors. His speech was fragmentary and staccato in quality. All tendon reflexes were hyperreactive, and Babinski's sign was positive on both sides; however, sensory disturbances in the peripheries of all extremities, such as those that commonly occur in methyl mercury intoxication, were not observed. He had difficulty in visual fixation, and showed slight peripheral constriction of the visual field of the left eye. This sign, however, recovered simultaneously, with other neurologic disorders.

Mercurialentis (Atkinson's lens reflex), a brownish-colored reflex, was observed in both eyes by slit lamp microscopy (Figure 2).

Figure 1 Gingivitis of chronic mercury poisoning. A characteristic blue-purple line occurs on the upper and lower gums.

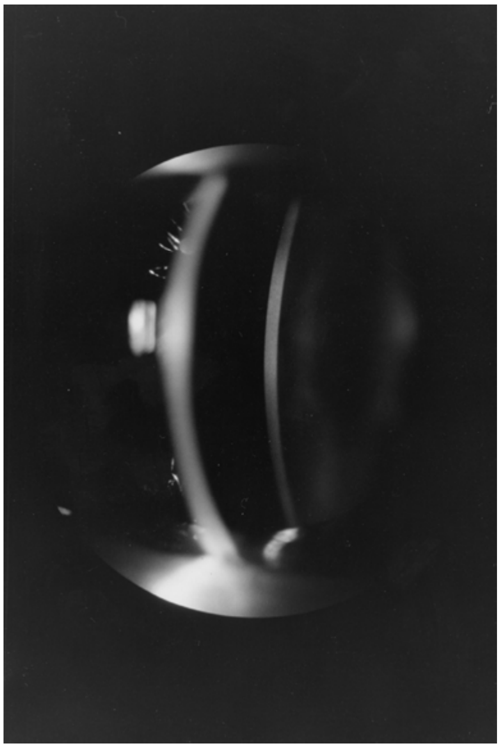


Figure 2 Brownish-colored reflex from the anterior capsule of the lens. The color of the reflex is deeper in the papillary area

Results

Relation between mercury in air and effects

Table 1 shows mercury levels in air of the work environment and mercury concentrations in blood and urine of workers in factories which handled metallic mercury. Mercury concentrations in air showed the highest value in the thermometer factory, followed by clinical thermometer factories, a chloralkali plant, and chemical production plant. Mercury concentrations in biological samples were also observed at the highest values in the thermometer factory workers. In these factories, workers consisted of the employer, employer's family, and employees. Table 2 shows symptoms of the thermometers factory workers who showed high mercury levels in the blood and urine. Tremors, speech disorder, ataxia, salivation, and irritability were observed in these workers as major symptoms of mercury poisoning. The relation between mercury concentrations in blood and urine and the severity of tremors in the manufacturing factories is shown in Figure 3. When the urinary mercury concentration exceeded 300 μg/l and blood mercury concentration exceed 100 ng/ml, increases in the prevalence of tremors were observed. However, there was no definite dose-response relationship between the mercury concentrations in blood and urine and tremor severity.

Table 1. Mercury levels in environmental air and mercury concentrations in blood and urine of workers.

Type of industry	Air Hg ($\mu g/m^3$)	Blood Hg (ng/ml)	Urine Hg ($\mu g/l$)
Glass thermometer (n=9)*	84 (42〜312)**	〜278	〜1950
Clinical thermometer (n=2)*	32 (15〜49)**	〜 50	〜 181
Chloralkali plant (n=11)*	15 (2〜47)**	〜 63	〜 218
Chemicals (n=1)*	59	〜 55	〜 127

* The number of factories is in parenthesis.
**Data are presented as mean values and each value in parenthesis presents the range.

Table 2. Mercury levels in blood and urine and symptoms of mercury thermometer workers.

No	Age	Sex	Blood Hg ng/ml	Urine Hg $\mu g/l$	Symptom
1	37	M	126	807	Tremors, speech disorder, ataxia, salivation, irritability
2	30	M	260	715	
3	45	M	245	795	Tremors, irritability
4	58	M	377	2963	Tremors, speech disorder, ataxia
5	28	M	114	670	
6	26	M	156	200	
7	42	M	176	1945	Tremors
8	55	M	159	1159	
9	42	M	163	1409	
10	53	M	134	973	
11	56	M	191	1416	
12	49	M	187	1988	Tremors, speech disorder
13	59	M	278	116	Tremors, speech disorder ,
14	22	M	107	275	
15	43	M	145	1180	
16	43	M	130	300	Speech disorder

Concentrations of total protein and β_2-microglobulin in the urine were usually used as an indicator of renal function disturbance. There was no significant correlation between the mercury concentration and total protein or β_2-microglobulin concentrations, as shown in Figure 4.

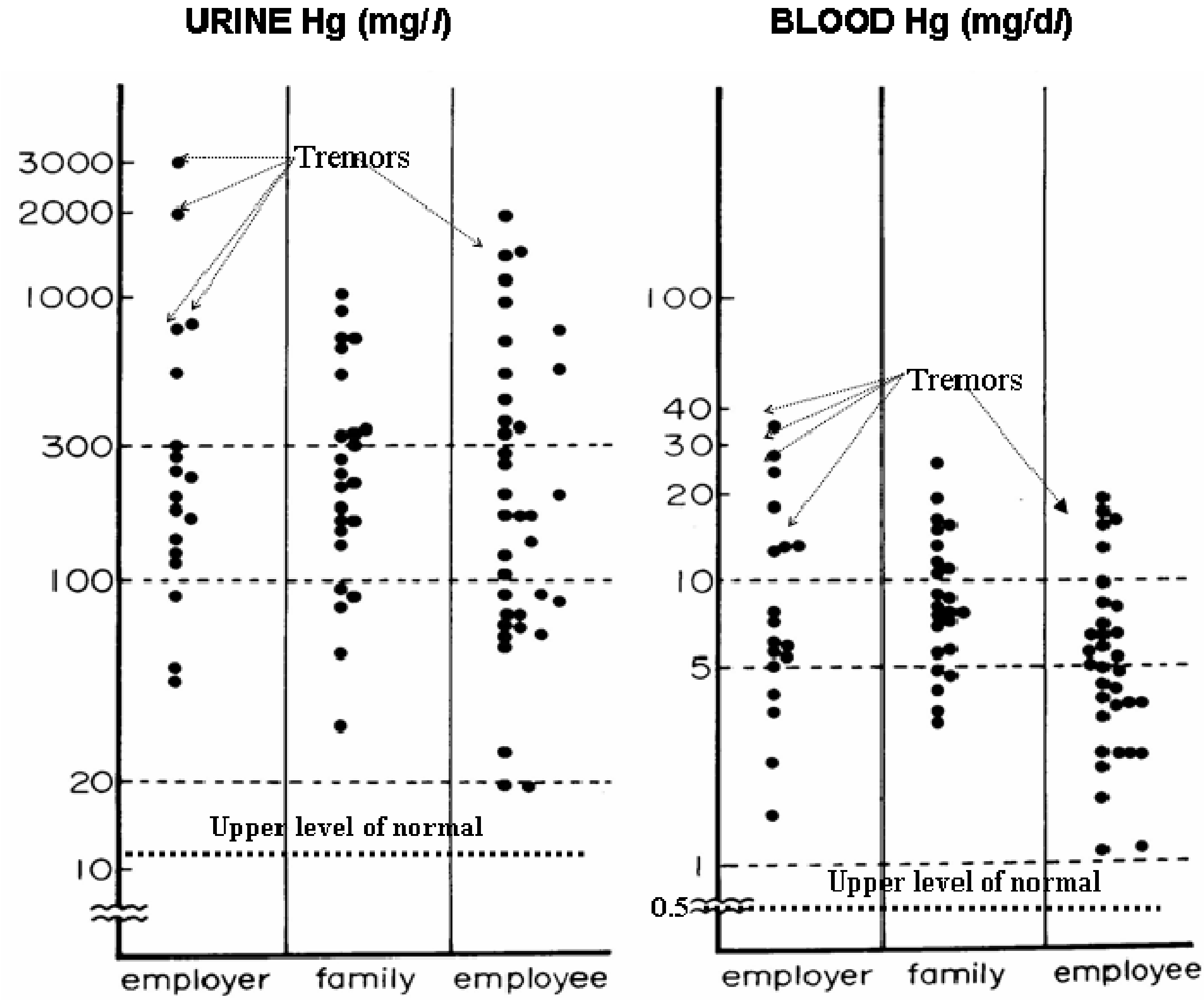


Figure 3 Mercury concentration in the urine and blood of workers in thermometer manufacturing factories.

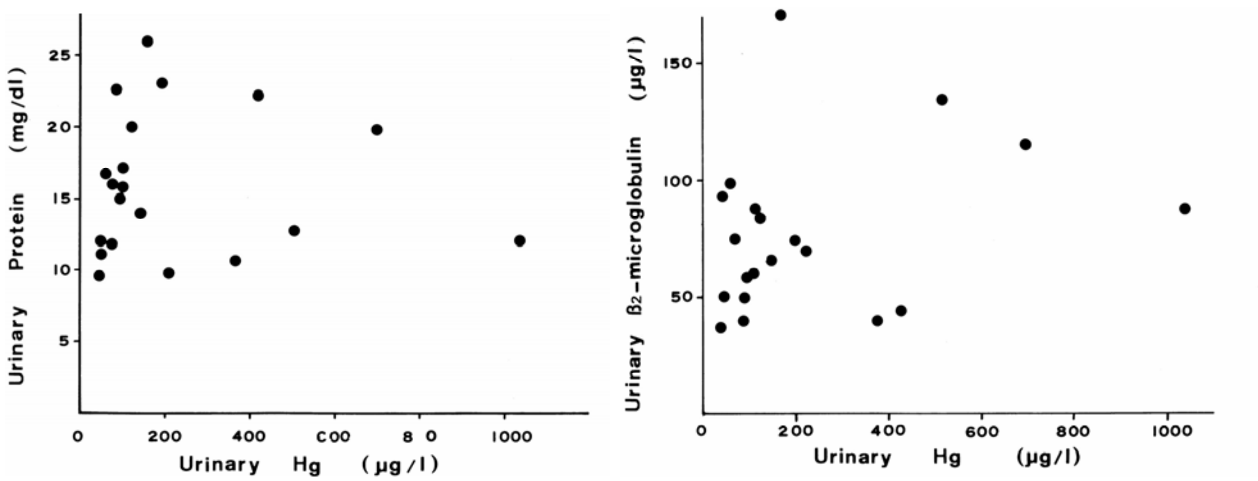


Figure 4 Urinary total protein and β_2-microglobulin concentrations of workers in thermometer factories.

Relation between mercury in urine or blood and exposure

Figure 5 illustrates the relationship between the levels of individual mercury exposure and concentration of mercury in the urine of thermometer factory workers. A good correlation coefficient was obtained between the mercury concentrations of the blood and the levels of individual mercury exposure (r=0.876, p<0.01). The correlation between the mercury concentration of the urine and the mercury exposure levels was also high (r=0.756, p<0.01). Further, more a significant correlation was found between the blood mercury levels and the urinary mercury levels (r=0.827, p<0.01). It is estimated that a mercury level of 0.1 mg/m^3 in the air corresponds to a 60 to 70 ng/ml blood mercury level and 100 to 230 mg/l urinary mercury level from the regression line.

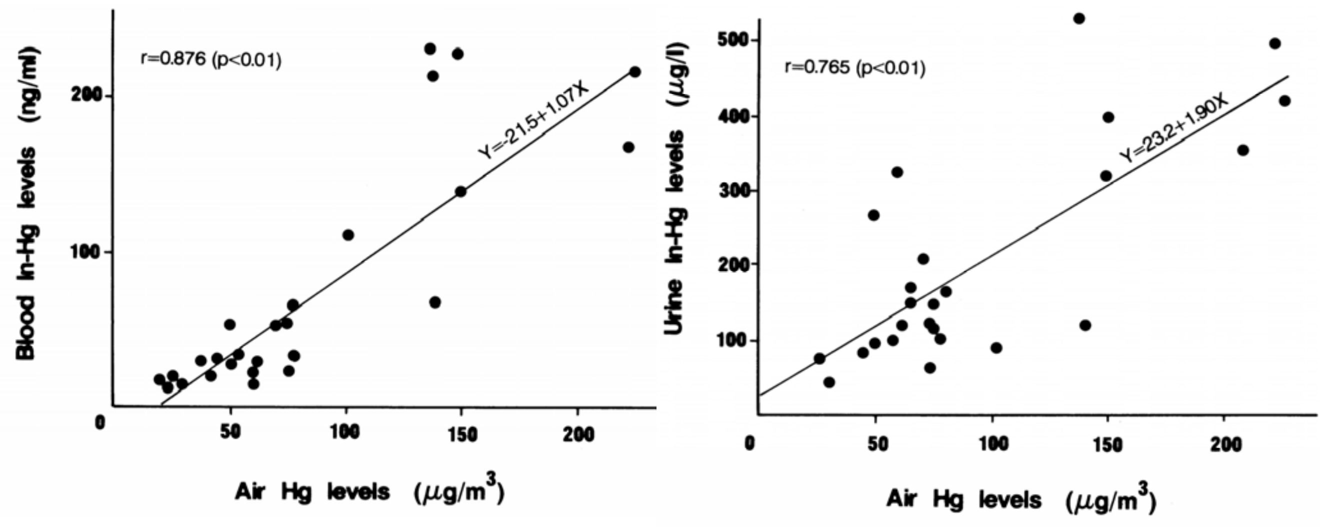
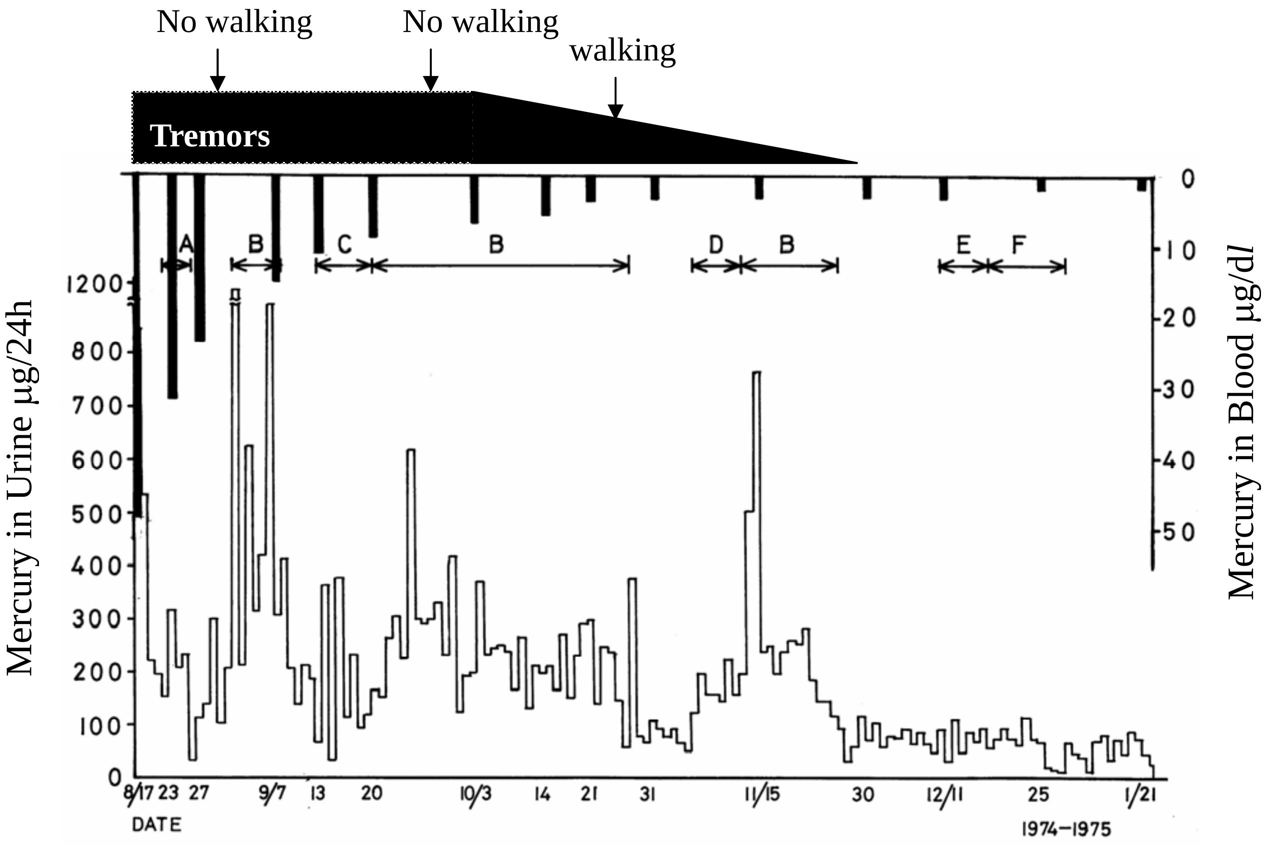


Figure 5 Relation of mercury exposure levels to mercury concentrations in the urine and blood

A case of chronic mercury poisoning

Mercury levels in the blood and urine of a patient with chronic mercury poisoning after hospitalization are shown in Figure 6. On admission, the mercury level was very high, with 572 ng/ml in the blood and 1910 μg/l in the urine. During medication with D-penicillamine, 1000 mg/day, tremor and weakness were transiently aggravated, so that he could not even sit up in bed. However, these mercury levels gradually decreased with time and the symptoms of mercury intoxication were also normalized thereafter, and the patient was discharged in six months. Writing samples on admission and three months after hospitalization are shown in Figure 7. After three months, the tremors considerably improved and his writing also became legible.



A:D-penicilamine 1000mg/d, B:D- penicilamine 600mg/d,
C: D- penicilamine 400mg/d, D:Thiola 1000mg/d,

Figure 6 Mercury concentrations in urine and blood, and the extent of tremors in patient during the period of hospitalization

On admission Three month after admission

Figure 7 Writing samples of a patient on admission and three month after hospitalization.

Exposure of the family to mercury vapor in the refining mercury factory

The refining of metallic mercury was performed in one of the rooms of the patient's family residence. Mercury levels in the air of the residence were 82-115 μg/m^3 in the living room which was adjacent to the working place, and 12 μg/m^3 in the bed room on the second floor. Table 3 shows mercury concentrations in blood and urine and health examination of his family. Mercury levels in the blood and urine were very high in both his wife and child.

Table 3. The mercury concentrations in blood and urine and symptoms of a mercury refining plant worker and his family.

	Age	Blood Hg (ng/ml)	Urine Hg (μg/l)	Symptoms
Patient	54	508	1910	Tremors, ataxia, irritability, gingivitis, salivation, missing teeth
Wife	44	320	2080	Light tremors
Child	7	300	-	Metal retardation, stomatitis

The wife, a 44-year-old woman, had often been attacked by hand tremors in the past, but at the time of the initial examination, tremors were slight. She had a history of two pregnancies, one of which had terminated in miscarriage. Their child, a 7-year-old girl, showing severe mental retardation and stomatitis, was admitted to St. Marianna University School of Medicine's hospital. She became mentally disturbed at three years old. Thereafter, she became unable to talk and later showed psychic irritability and relapsing stomatitis. Mercury concentrations in the blood and urine of the infant during the period of hospitalization are shown in Figure 8. On admission, mercury levels were about 5 times higher in the blood and about 600 times higher in the urine than in controls. These mercury levels, however, gradually decreased with time. Six months after admission, her motor function and activities improved, but her speech did not improve.

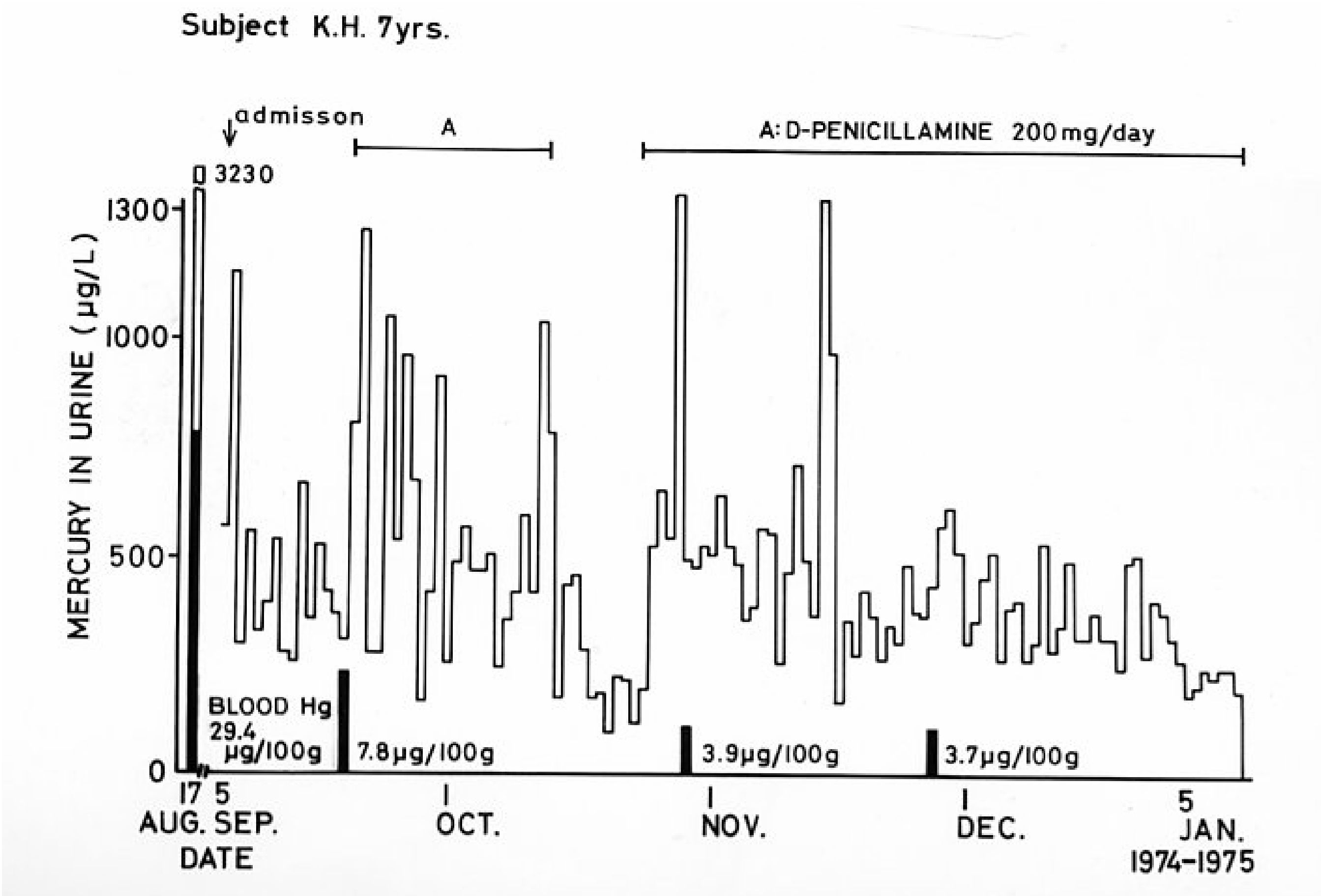


Figure 8 Mercury concentration in urine and blood of a child of a mercurialism patient during the period of hospitalization.

Discussion

In chronic exposure to relatively low concentrations of mercury vapor, neurological changes are prominent. The signs and symptoms of mercury vapor poisoning are characterized by gingivitis, intentional tremors and erethism, and in addition, weakness, fatigue, loss of weight, and disturbance of gastrointestinal functions appear unspecifically (WHO, 1991). With regard to the relation between blood mercury levels and the symptoms of chronic mercury poisoning, Benning (1958) described that there was no direct correlation between the toxic symptoms and mercury levels in the blood and urine. Ladd et al. (1966) also described that there was no difference in mercury levels in the blood and urine between workers with symptoms of mercury poisoning and asymptomatic workers in a survey on mercury miners. On the other hand, Smith et al. (1970) showed that when such workers were investigated as groups, there was an intimate correlation between the symptoms of intoxication and mercury levels in the blood. In studies of industries where exposure has been high, Langolf et al. pointed towards the importance of urine mercury peaks in excess of 500 μg/l for the development of neurological signs and symptoms. Further, Forzi et al. (1976) reported that urine mercury peaks in excess of 100 μg/l were associated with impaired performance in mechanical and visual memory tasks and psychomotor ability test. In a survey on workers engaged in the manufacturing of mercury thermometers, when the mercury concentration exceeded 300 μg/l in the urine or 100 ng/ml in the blood, an increase in the prevalence of tremors was observed. However, typical signs and symptoms of chronic mercury poisoning such as tremors, speech disorder, ataxia, irritability, and salivation were not observed in workers who had urinary mercury levels of less than 100 μg/l.

Occupational exposure to mercury vapor has long been associated with the development of proteinuria. Joselow and Godwater (1967) demonstrated that the prevalence of proteinuria in mercury workers was high as compared with a control group, and a significant correlation was observed between urinary mercury and protein excretion. On the other hand, Stonard et al. (1983) reported that when they examined chloralkali industry workers with an average urine mercury level of 67 μg/g creatinine, there was no evidence of renal dysfunction and no increased excretion of proteins. Examination of urinary β_2-microgloblin was used as an indicator of renal proximal tubular dysfunction. Schaller et al. (1980) found a slight increase in urinary β_2-microgloblin levels of workers with urine mercury levels of 53-746 mg/g ceatinine. Roles et al. (1978), however, described that an increase in urinary β_2-microgloblin excretion could not be observed in mercury workers with a urine mercury level of 6-97 μg/g creatinine. The total protein and β_2-microgloblin levels in the urine of thermometer manufacturing workers showed no significant differences compared to the control. There were also significant correlation between the mercury concentration and total protein and β_2-microgloblin levels. These results suggest that the total protein and β_2-microgloblin levels in the urine may be not useful indicators of renal dysfunction following mercury vapor exposure.

In factories handing metallic mercury, the determination of mercury in urine or blood, as well as air concentration analysis, have played an important role in evaluating the extent of mercury exposure as well as the degree of risk. Smith et al. (1970) reported a correlation between mercury exposure levels and urinary or blood mercury concentrations. Also, urinary mercury is known to correlate well with individual mercury exposure, as determined by the personal monitoring technique. Our data also showed that when the evaluation of mercury exposure levels on the basis of personal monitoring is carried out, the mercury levels in the urine and blood correlate well with the levels of mercury exposure for each worker. Further, mercury exposure to 0.1 mg/m^3 corresponds to mercury levels of 70 ng/ml in blood, and 180 μg/l in urine. These values agreed with the values estimated by Smith et al. (1970) and Lindstedt at al. (1979), whereby the mercury levels in blood corresponding to a mercury exposure of 0.1 mg/m^3 were in the range of 60 to 70 ng/ml, and urinary levels in the range of 200 to 230 μg/l, respectively. Our findings, therefore, indicate that mercury levels in the urine and blood are useful biological monitors for assessing the level of exposure to mercury vapor.

In various factories dealing with metallic mercury, the occurrence of chronic mercury poisoning has been reported by many researchers. Yamamura et al. (1973) also found that employees and non-occupational families who lived in a house together were exposed to high concentrations of mercury vapor in small-scale factories handing metallic mercury such as a thermometer factory. The mercury concentration in the blood and urine of the families as well as the workers were very high compared to the controls. They described that the rooms of the family residence were adjacent to the working place, and the mercury levels in the family rooms showed a high value exceeding the TLV of WHO. In a case with severe signs and symptoms of mercury poisoning, the refining of metallic mercury was performed in the working place, which was adjacent to the living room. Mercury levels in the air of the living room were above 0.1 mg/m^3 at all times. When the measurement of mercury concentrations in the biological samples and health examination of the patient's family were performed, the wife suffered from slight mercury poisoning. On the other hand, the child showed mental disturbance at three years old, and was observed with symptoms of severe mental retardation, photophobia, and stomatitis which seem to be caused by mercury vapor exposure at seven years old. The wife's symptoms of mercury poisoning was improved by isolation form exposure to mercury vapor by hospitalization. In the child, the motor function and activities improved with a decrease in mercury levels in the blood and urine as well as her mother, but her loss of speech recovered little. Recently, Cherry et al. (2002) reported long-term exposure to mercury vapor from a metallic mercury spill in a family residence. Over a period of 6 months of exposure to mercury vapor, a 3-year-old child in the household presented with progressive weight loss, irritability, tremors, abnormal EEG, loss of speech and language, and ataxia. Exposure to mercury vapor during the gestation period is also known to adversely affect fetal development. It is not clear whether the symptoms of mercury poisoning in the 7-year-old child are via the influence of mercury exposure during the gestation or development period. This evidence, however, indicates that exposure to mercury vapor during periods of gestation and development has an adverse effect on child development in later year.

Hudson et al. (1987) reported that urinary mercury levels of children of thermometer plant workers are higher than those of children in a control group, and higher mercury levels in the air were measured in the homes of thermometer plant workers to control group homes. In this study, they also described that because workers inadvertently transport the mercury to their homes via their clothing and shoes, the risk of mercury poisoning for families of workers further increases. Many small-scale mercury thermometer factories which we investigated had a workshop and a residence in a house. In such a factory, a family will always be exposed to the risk of mercury toxicity as well as worker.

In conclusion, when the measurement of mercury levels in working environments such as a small-scale mercury manufacturing factory is difficult, the monitoring of mercury in urine and blood is not only a useful tool in the evaluation of exposure to mercury vapor, but also helpful in the prevention of mercury poisoning. In addition, metallic mercury-handling work in a house should be avoided to prevent of mercury exposure to the family.

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Mercury Pollution in China

Jian-bo Shi, Gui-bin Jiang

State Key Laboratory of Environmental Chemistry and Ecotoxicology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences

Mercury is listed as a priority pollutant because its persistence, bioaccumulation and toxicity (PBT) in the environment. In fact, anthropogenic sources, such as coal combustion, Hg mining, non-ferrous smelting and manufacturing of products using or containing Hg etc., are primary sources for the global Hg contamination. With the rapid development of industry and agriculture in last century, the amount of Hg consumed in China was significantly increased. China is the largest coal producer and consumer in the world. As of 2001, China consumed nearly 1270 million tones (Mt) of coal, accounting for 26.2% of the world's total coal consumption. China contributed about 25% of annual global anthropogenic Hg emissions. The large amount of released Hg brought serious Hg pollution in China. This presentation will introduce the sources and contamination status of Hg pollution and risk assessment in China.


Mercury Pollution in China
-----Focus on Speciation Methodologies and Distributions
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水俣
MINAMATA


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This is to certify that
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Chinese Academy of Sciences, China
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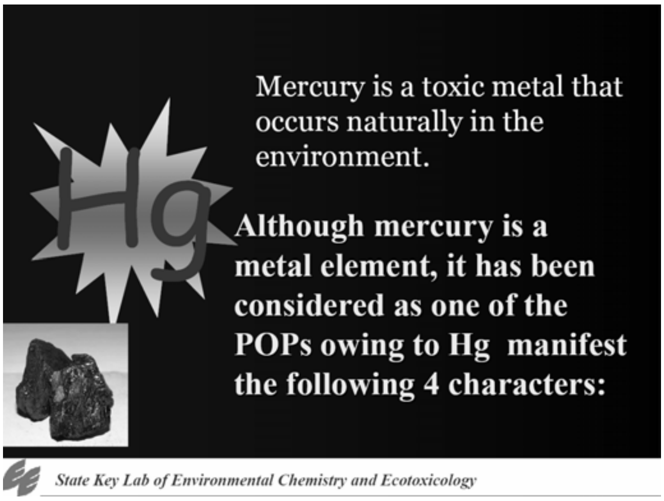
5 3 2003


Hg
Mercury is a toxic metal that occurs naturally in the environment.
Although mercury is a metal element, it has been considered as one of the POPs owing to Hg manifest the following 4 characters:
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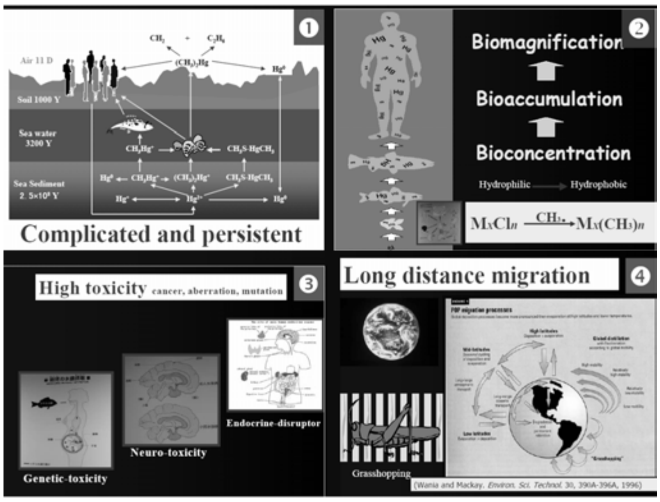
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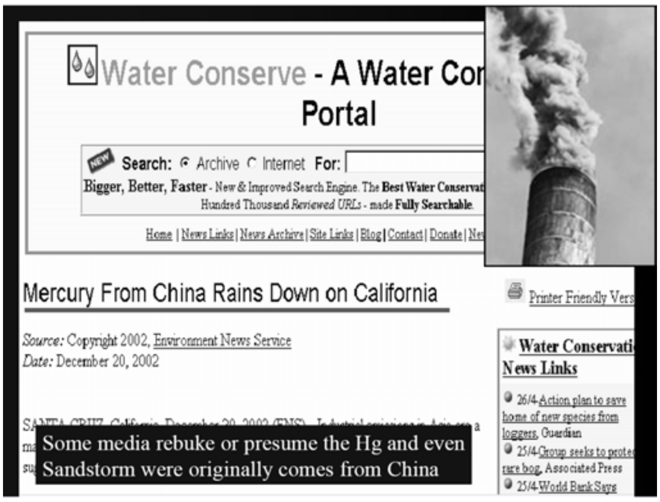
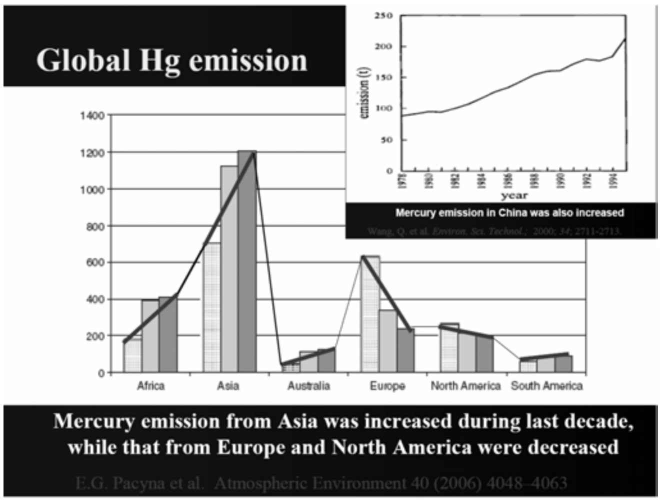
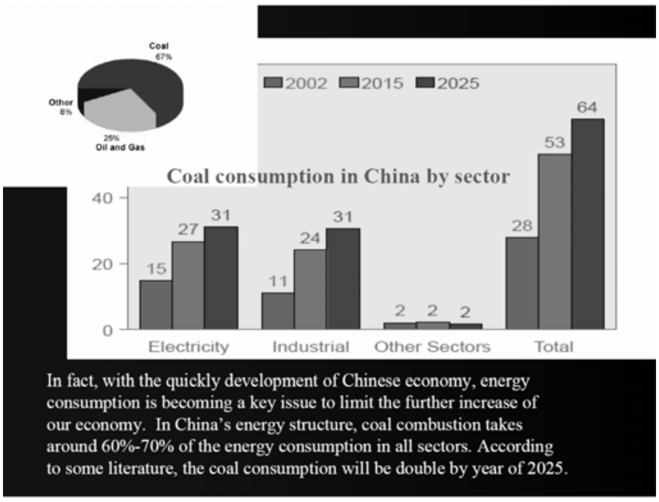
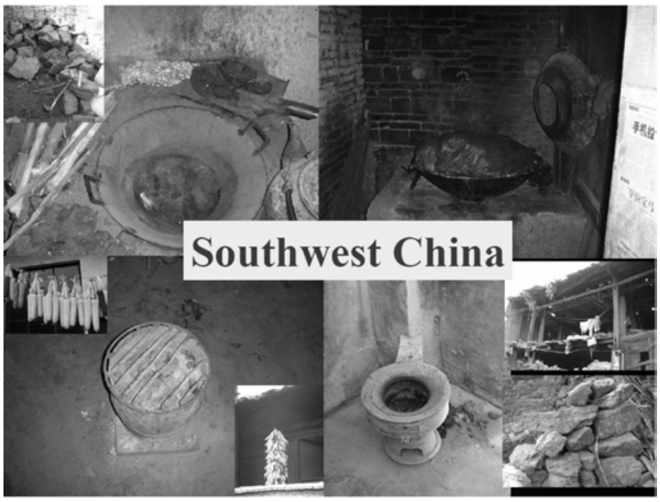
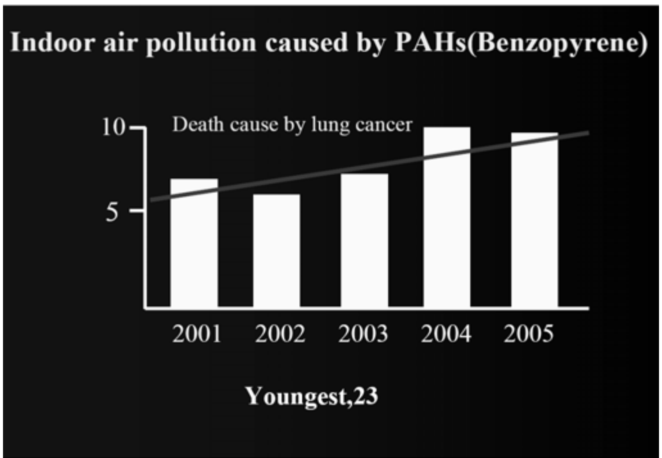
Air 11 D
Soil 1000 Y
Sea water 3200 Y
Sea Sediment 2.5×10⁸ Y
Complicated and persistent
2
Biomagnification
Bioaccumulation
Bioconcentration
Hydrophilic → Hydrophobic
MxCln —CH3→ Mx(CH3)n
3
High toxicity cancer, aberration, mutation
Genetic-toxicity
Neuro-toxicity
Endocrine-disruptor
4
Long distance migration
Grasshopping
(Wania and Mackay. Environ. Sci. Technol. 30, 390A-396A, 1996)











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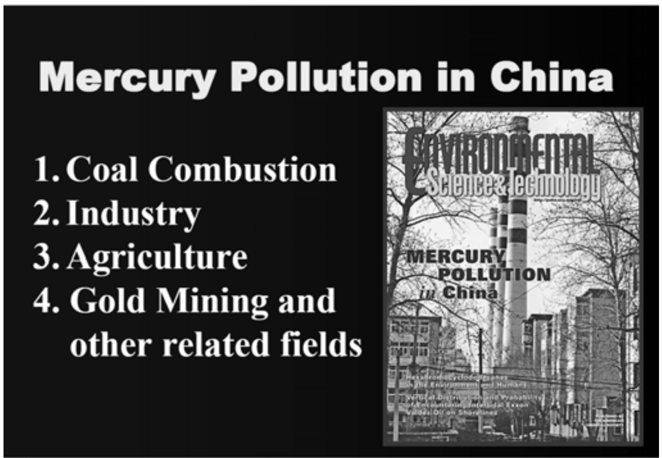

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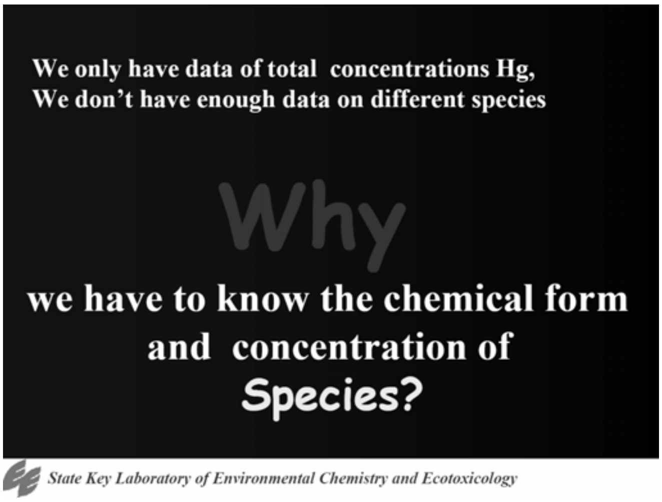
We only have data of total concentrations Hg,
We don't have enough data on different species
Why
we have to know the chemical form
and concentration of
Species?
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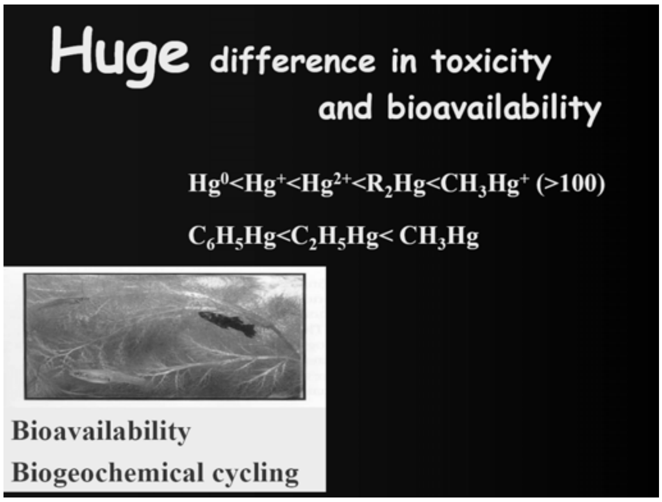
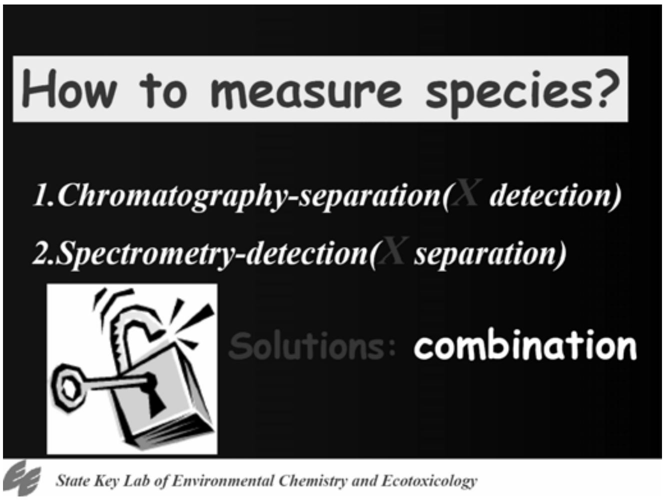

Huge difference in toxicity
and bioavailability
$Hg^0 < Hg^+ < Hg^{2+} < R_2Hg < CH_3Hg^+$ (>100)
$C_6H_5Hg < C_2H_5Hg < CH_3Hg$
Bioavailability
Biogeochemical cycling


How to measure species?
1.Chromatography-separation(X detection)
2.Spectrometry-detection(X separation)
Solutions: combination
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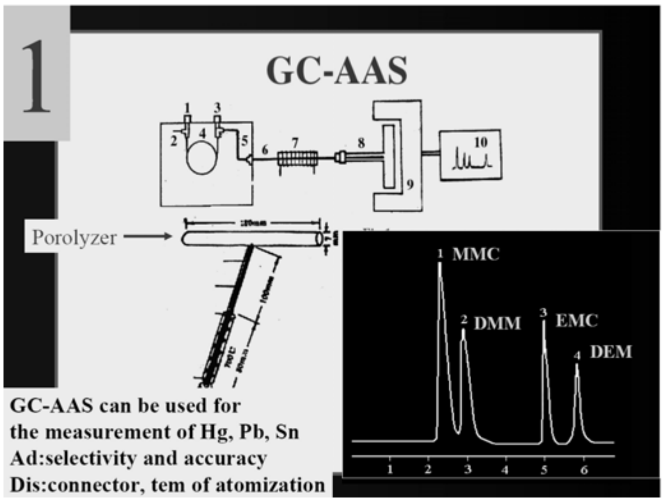
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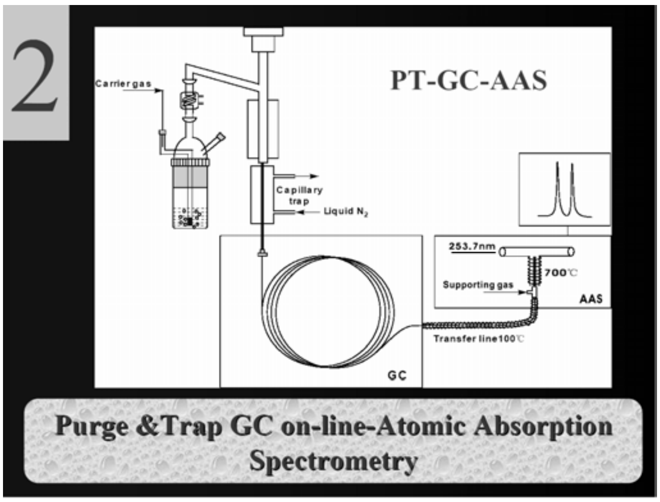
GC-AAS
Porolyzer
MMC
DMM
EMC
DEM
GC-AAS can be used for
the measurement of Hg, Pb, Sn
Ad:selectivity and accuracy
Dis:connector, tem of atomization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Carrier gas
Capillary trap
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Supporting gas
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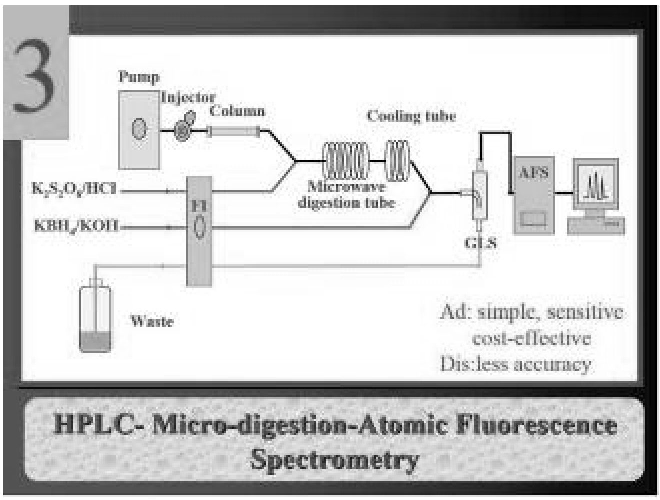
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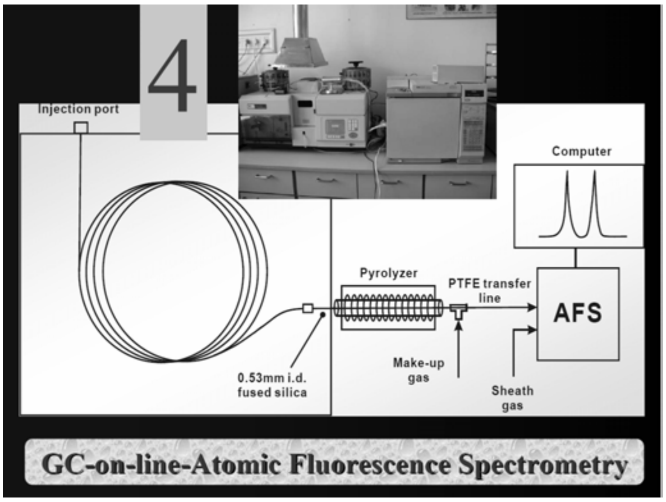
Pump
Injector
Column
Cooling tube
$K_2S_2O_8$/HCl
KBH_4/KOH
FI
Microwave digestion tube
GLS
AFS
Waste
Ad: simple, sensitive
cost-effective
Dis:less accuracy
HPLC- Micro-digestion-Atomic Fluorescence Spectrometry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Make-up gas
Sheath gas
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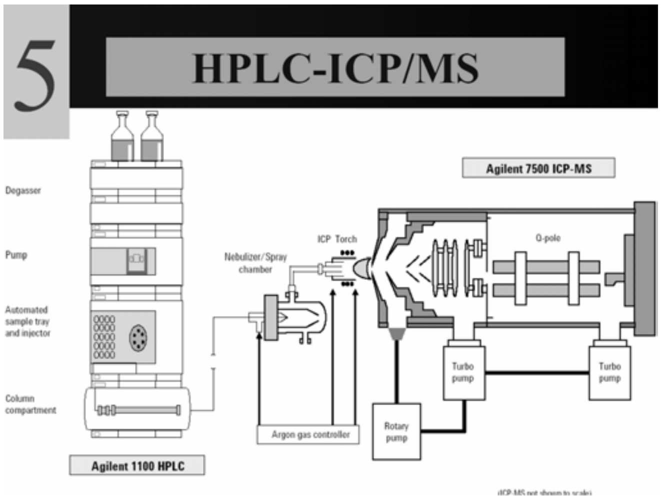
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Column compartment
Nebulizer/Spray chamber
ICP Torch
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Turbo pump
Turbo pump
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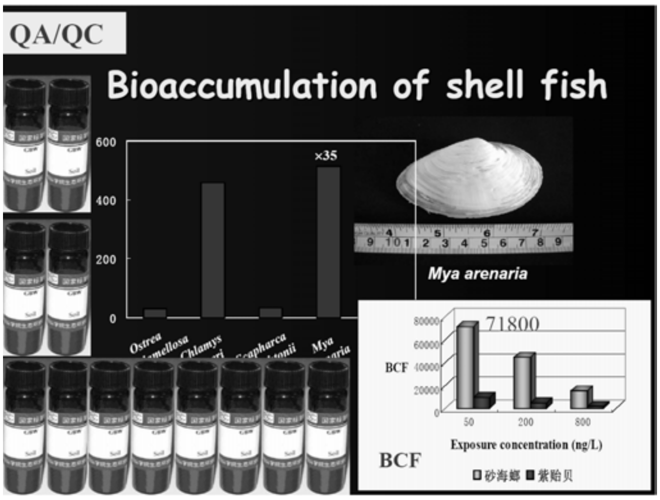
Agilent 1100 HPLC


QA/QC
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Ostrea
Chlamys
Scapharca
Mya
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BCF
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Exposure concentration (ng/L)
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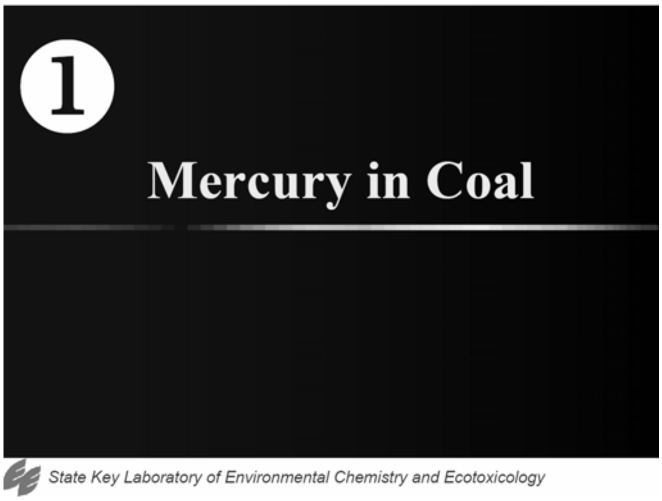
1
Mercury in Coal
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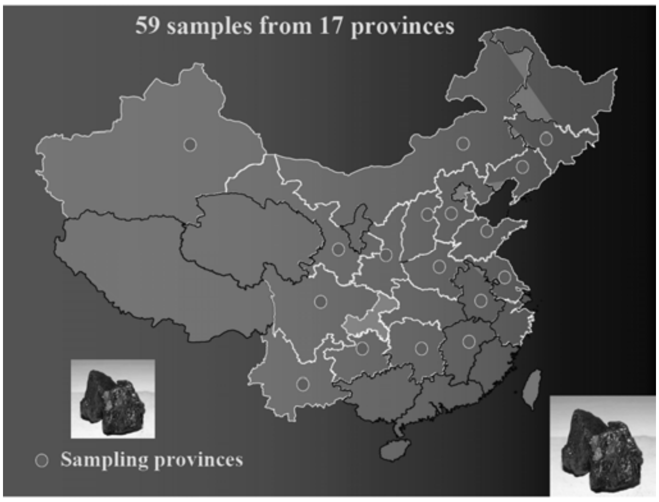
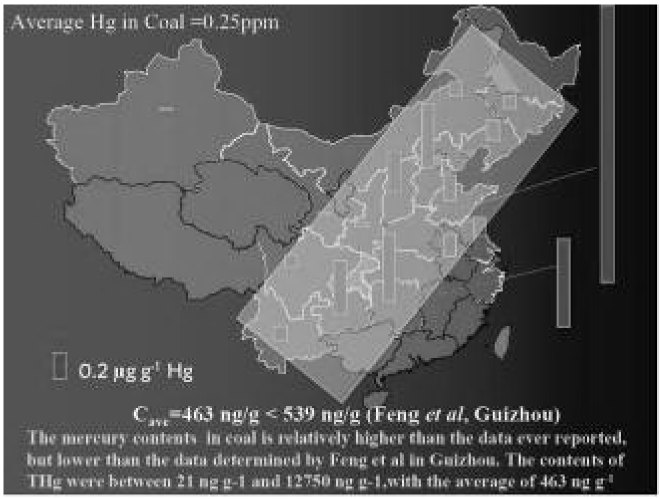
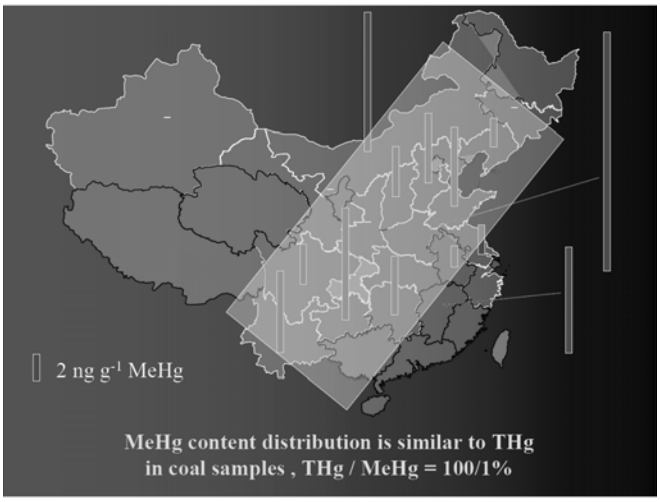
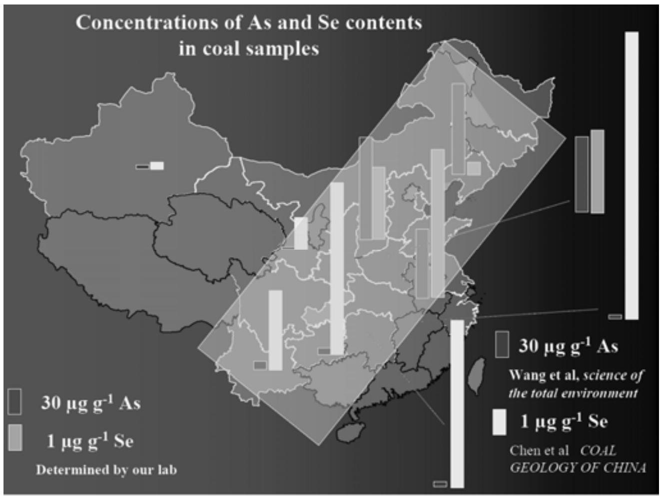
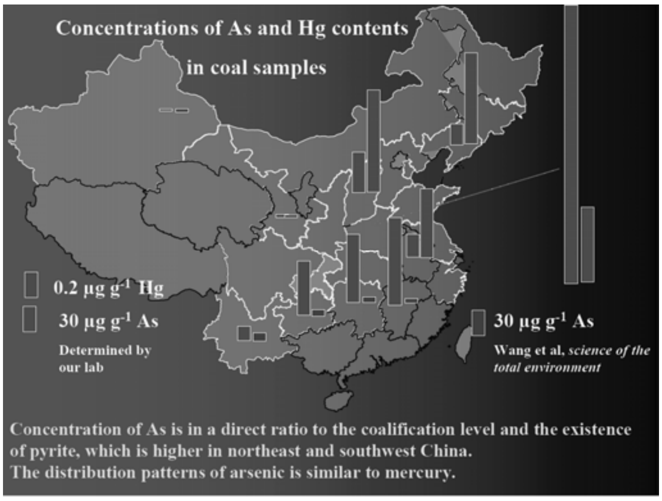
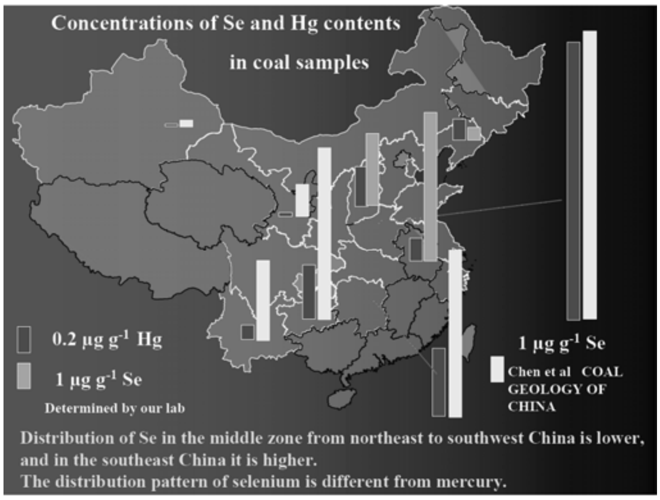

59 samples from 17 provinces
Sampling provinces

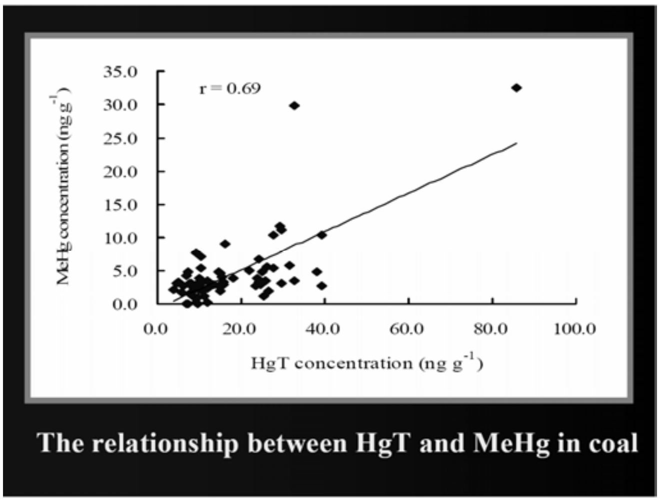

Average Hg in Coal =0.25ppm
0.2 μg g⁻¹ Hg
C_ave=463 ng/g < 539 ng/g (Feng et al, Guizhou)
The mercury contents in coal is relatively higher than the data ever reported, but lower than the data determined by Feng et al in Guizhou. The contents of THg were between 21 ng g-1 and 12750 ng g-1,with the average of 463 ng g⁻¹

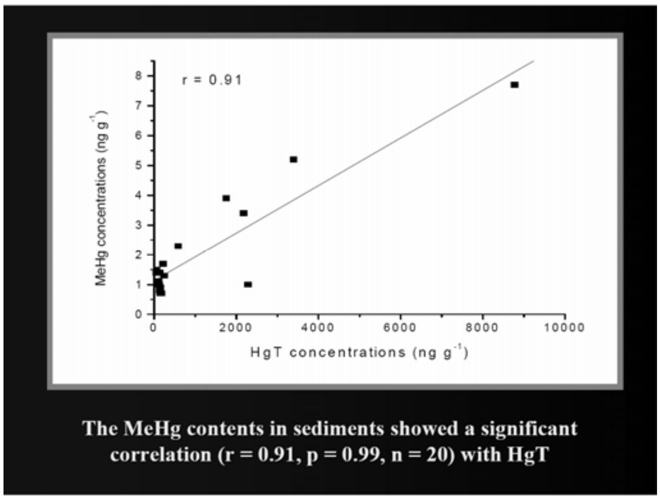

2 ng g-1 MeHg
MeHg content distribution is similar to THg
in coal samples , THg / MeHg = 100/1%

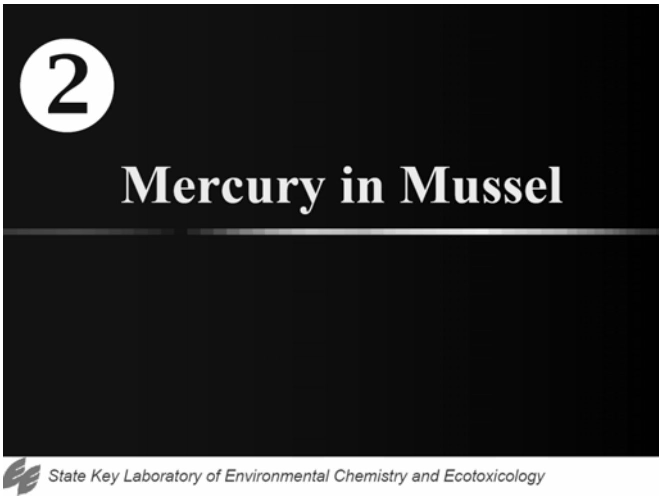

Concentrations of As and Se contents
in coal samples
30 μg g-1 As
Wang et al, science of the total environment
1 μg g-1 Se
Chen et al COAL GEOLOGY OF CHINA
30 μg g-1 As
1 μg g-1 Se
Determined by our lab

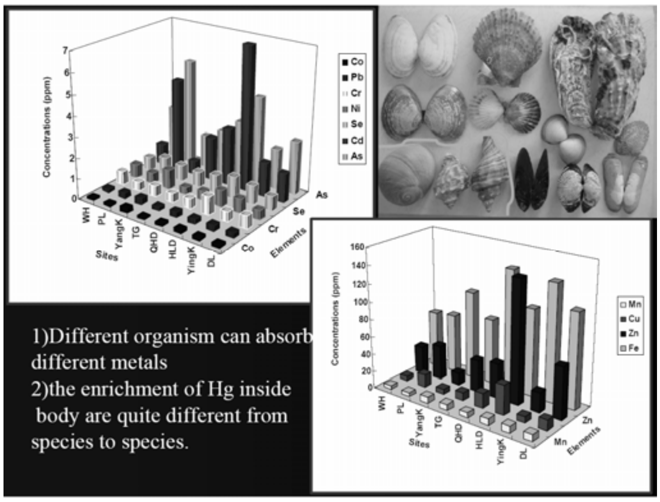

Concentrations of As and Hg contents
in coal samples
0.2 μg g-1 Hg
30 μg g-1 As
Determined by our lab
30 μg g-1 As
Wang et al, science of the total environment
Concentration of As is in a direct ratio to the coalification level and the existence of pyrite, which is higher in northeast and southwest China.
The distribution patterns of arsenic is similar to mercury.

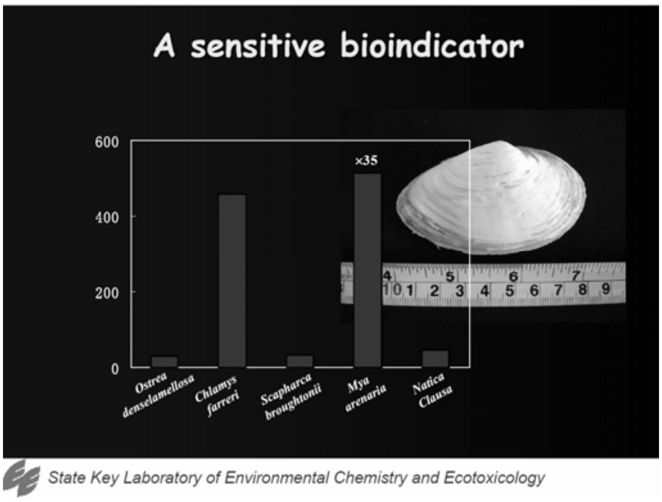

Concentrations of Se and Hg contents
in coal samples
0.2 μg g-1 Hg
1 μg g-1 Se
Determined by our lab
1 μg g-1 Se
Chen et al COAL GEOLOGY OF CHINA
Distribution of Se in the middle zone from northeast to southwest China is lower, and in the southeast China it is higher.
The distribution pattern of selenium is different from mercury.

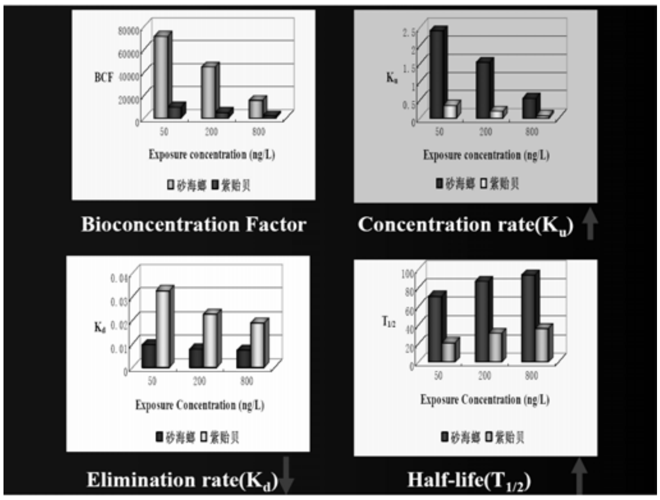

r = 0.69
MeHg concentration (ng g-1)
HgT concentration (ng g-1)
The relationship between HgT and MeHg in coal

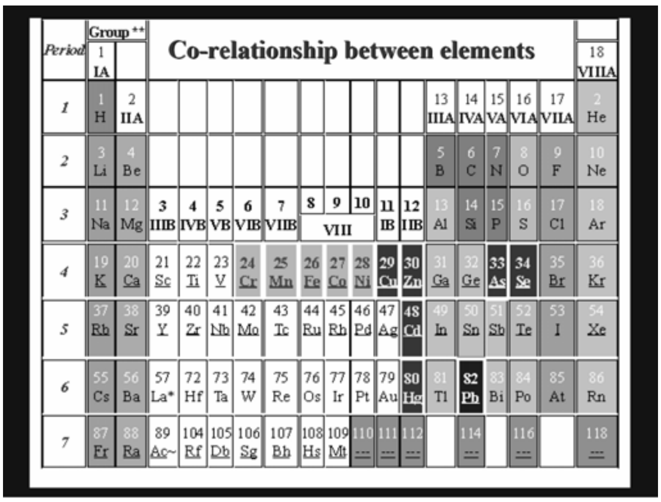

r = 0.91
MeHg concentrations (ng g-1)
HgT concentrations (ng g-1)
The MeHg contents in sediments showed a significant correlation (r = 0.91, p = 0.99, n = 20) with HgT


2
Mercury in Mussel
State Key Laboratory of Environmental Chemistry and Ecotoxicology

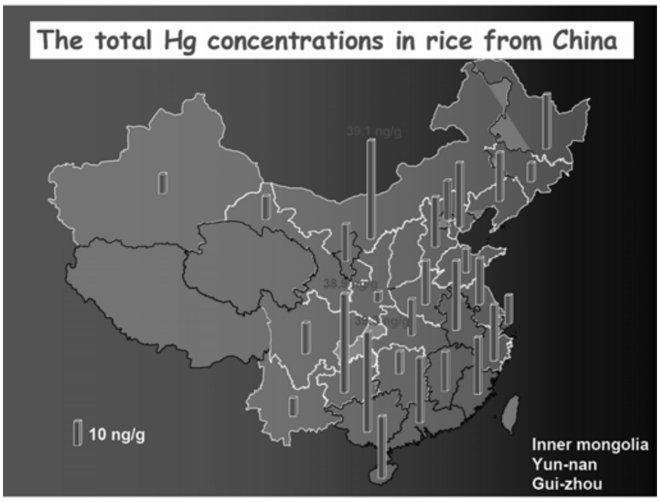

Concentrations (ppm)
Sites
Elements
WH PL YangK TG QHD HLD YingK DL
Co Pb Cr Ni Se Cd As
Mn Cu Zn Fe
1)Different organism can absorb different metals
2)the enrichment of Hg inside body are quite different from species to species.

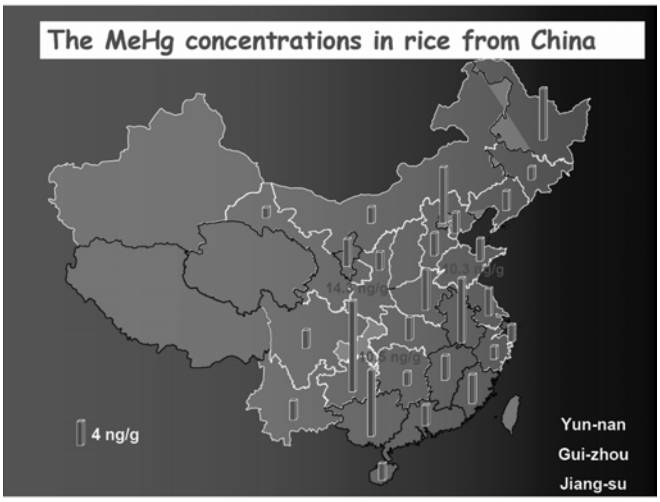

A sensitive bioindicator
×35
Ostrea denselamellosa
Chlamys farreri
Scapharca broughtonii
Mya arenaria
Natica Clausa
State Key Laboratory of Environmental Chemistry and Ecotoxicology


BCF
Exposure concentration (ng/L)
砂海螂 紫贻贝
Bioconcentration Factor
Concentration rate(K_u)
Elimination rate(K_d)
Half-life($T_{1/2}$)


Co-relationship between elements
Period
Group **


3
Mercury in Food
State Key Laboratory of Environmental Chemistry and Ecotoxicology





Is rice safe for consumption?

If a person (60 Kg weight) eats 250g rice per day, the intake of HgT and MeHg from rice are 0.07 and 0.02 μ g / kg / day, respectively.

Recommended maximum values for dietary intake of HgT and MeHg (μ g / kg of body weight / day)

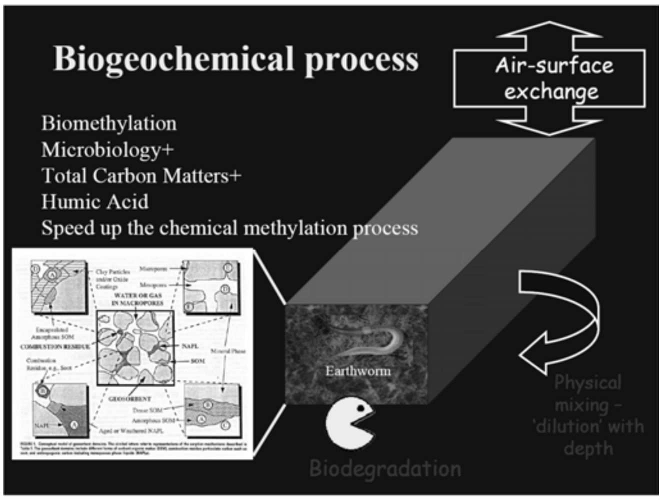
Organization	HgT	MeHg
FAO / WHO (1991)	0.71	0.47
US EPA (1997)	NA*	0.1

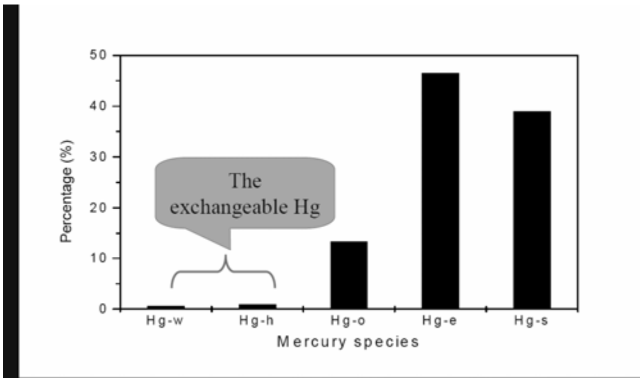
*** Not available**

4 Mercury and Bioavailability

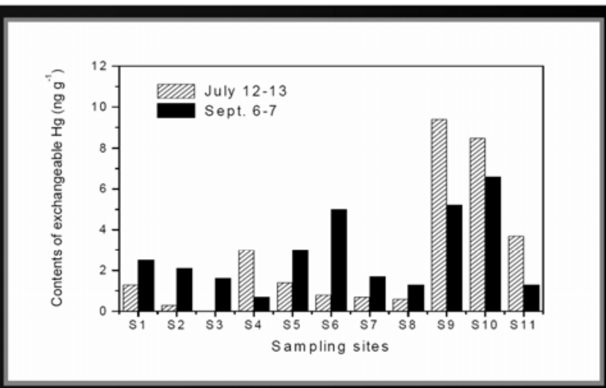
❺❻

State Key Laboratory of Environmental Chemistry and Ecotoxicology





Sequential extraction results: the Hg in sediments exists mainly as elemental Hg (Hg-e) and mercuric sulfide (Hg-s); The exchangeable Hg accounts for only 0.1%-4.6% (average: 1.1%), which have the highest bioavailability.



The distribution of exchangeable Hg was different with that of HgT contents in sediments, indicating that the total Hg concentrations were absolutely insufficient to evaluate the risk of Hg in sediments.

Some Puzzle Problems

1. Long-distance transportation
2. Toxicology(cell biology)
3. Bioaccumulation&Biotransformation
4. Geochemical mechanism

State Key Lab of Environmental Chemistry and Ecotoxicology

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- National Basic Research Program of China
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- (863,2003AA640610)
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- Chinese Academy of Sciences(KZCX2-414)

- All my colleagues and students who engaged in this work.

State Key Lab of Environmental Chemistry and Ecotoxicology

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Mercury Pollution to the Environment in Mercury Mining Areas in Guizhou, China

Xinbin Feng[1], Guangle Qiu[1], Ping Li[1], Mineshi Sakamoto[2], Xiaojie Liu[2], Toyoto Iwata[3], Minoru Yoshida[4]

[1]State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences
[2]National Institute for Minamata Disease, Ministry of the Environment, Japan
[3]Department of Environmental Health Sciences, Akita University School of Medicine
[4]Faculty of Human Health Sciences, Hachinohe University

Guizhou is known as the "mercury capital" of China because more than 60 % of total national mercury resources were discovered in this province. Guizhou is located in the Global Circum-Pacific Mercury Belt, and at least 12 large and super large-scale mercury mines have already been discovered in the province. We found that the tailings and calcine from past Hg mining activities are the important sources of Hg contamination to the local environment, such as surface water systems, soil compartment, food and vegetables. Concentrations of total mercury and methylmercury (MeHg) were measured in soil and vegetation samples collected from a small but long historic Hg-mining area. Simultaneously, Hg distributions were determined in stream-waters during two sampling periods. Total Hg concentrations in soil and vegetation samples were highly elevated ranging from 0.41 - 610 $mgKg^{-1}$ and from 0.02 - 55 $mgKg^{-1}$, respectively. MeHg concentrations varied from 0.41 - 8.8 μgKg^{-1} in soil samples and from 0.65 - 5.5 μgKg^{-1} in vegetations. The concentrations of total Hg in stream waters varied from 55.0 - 7,020 ngL^{-1} in the flood-flow regime and from 24.8 - 679 ngL^{-1} in the base-flow regime, respectively. Average dissolved Hg concentration was 15.7 ngL^{-1} in wet season and 21.0 ngL^{-1} in dry season. However, particulate Hg was typically > 70% of total Hg in the flood-flow regime. Higher concentrations of particulate Hg primarily originated from summer floods were the major pathway of Hg transportation, which were evidenced by the positive correlation between particulate Hg and total suspended solids (TSS). The contaminated soils and distribution patterns of Hg in the stream-waters suggest derivation from historic Hg-mining sites and may serve as an important additional source of Hg to the local environment in the study area. In Hg mining areas, long history of mining activities have produced serious Hg pollution to the local environment. Hair Hg levels indicated that the residents in Wanshan and Wuchuan Hg mining areas were exposed to Me-Hg. Rice as the staple food of the local inhabitants were also showed high T-Hg and Me-Hg levels. The peak value of T-Hg concentration in the rice was found to be 393 ng/g and the Me-Hg concentration was up to 20.9 ng/g. The percentage of Me-Hg as T-Hg in rice was up to 83.6%. The relationship between estimated rice Me-Hg intake and hair Me-Hg levels confirmed rice with high Me-Hg levels indeed was the main route of Me-Hg exposure in Wanshan and Wuchuan areas. Mercury exposures for smelting workers using indigenous method in Wuchuan mercury mining areas, Guizhou Province, China were evaluated by urine and hair mercury survey. The small scale mining activities have resulted in serious mercury pollution to the local environment. The TGM was up to 40 $\mu g/m^3$ near the smelting furnace in the study areas. The geometric mean value of urinary mercury for smelting workers was up to 463 μg/g Cr which was significantly higher than 1.24 μg/g Cr for residents in the control site. The mean value of urinary β2-MG content was up to 248 μg/g Cr for smelting workers contrast to 75.4 μg/g Cr for persons in control areas. Several workers already manifested some clinical symptoms of lightly chronic mercury poisoning and showed a serious adverse effect on renal system. Results indicated that the smelting workers were seriously exposed to mercury vapor through inhalation.

Mercury Pollution to the Environment in Mercury mining areas in Guizhou, China

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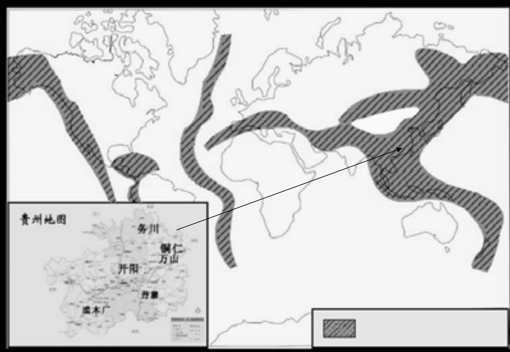
1 State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, China

2 National Institute for Minamata disease, Japan

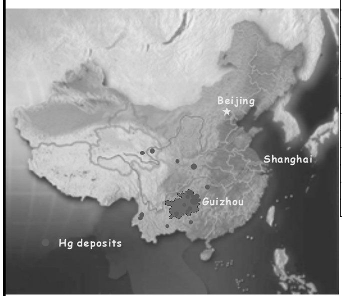
3 School of Medicine, Akita University, Japan

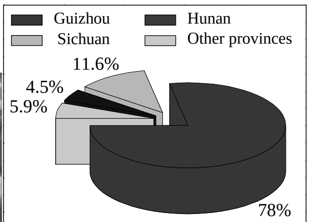
4. Faculty of Human Health Sciences, Hachinohe University, Japan

NIMD 2006 Forum II, November 28-29, 2006, Minamata, Japan



Hg deposits in China

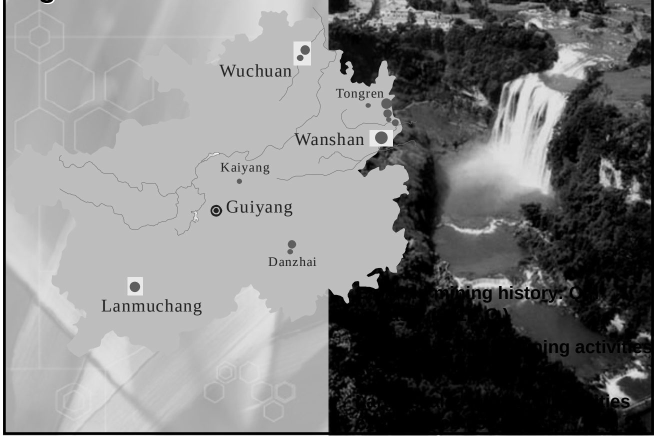




The distribution of cinnabar resources in China

Cinnabar resources in Guizhou: 90000 tons, accounting for 78% of the total in China

Hg mines in Guizhou



Outline

- **Mercury contamination to the local environment from historical large scale Hg mining activities and health impacts to local inhabitants**
- **Mercury contamination to the local environment from current small scale Hg smelting activities and health impacts to miners**

Outline

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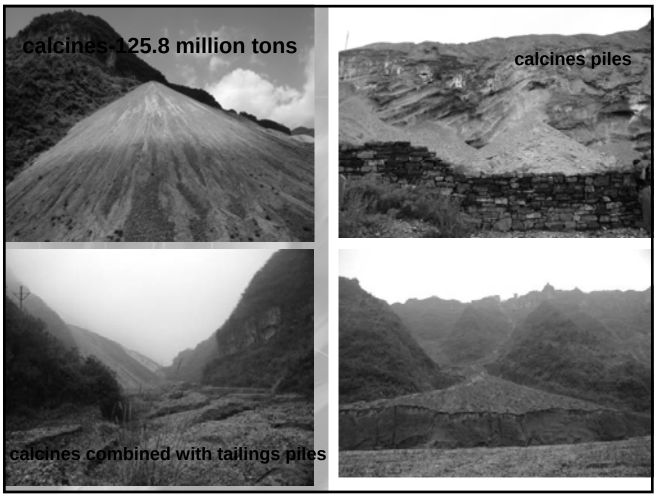
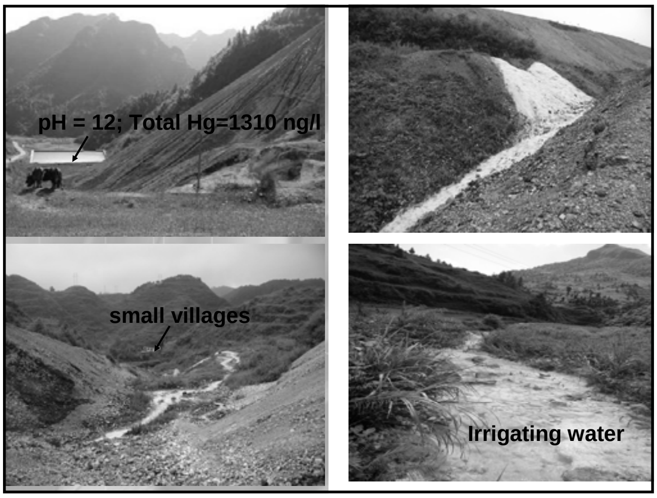
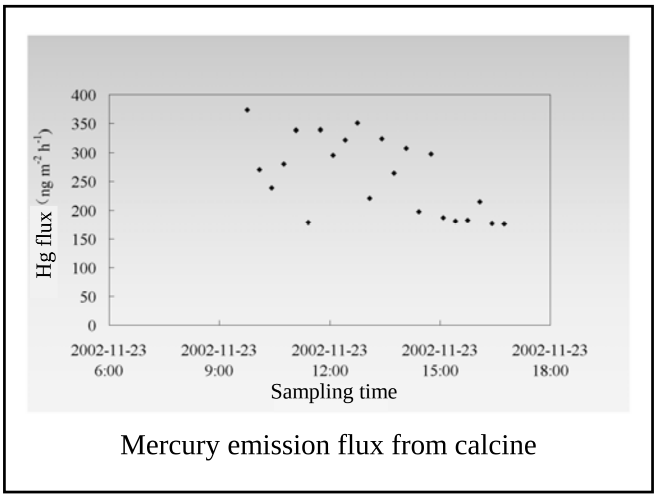
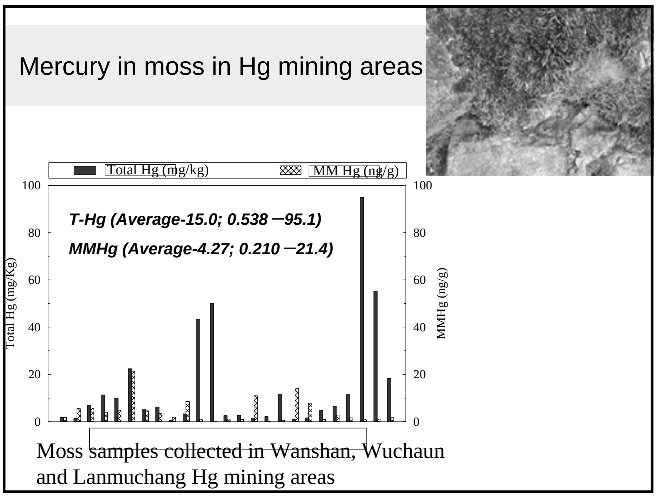
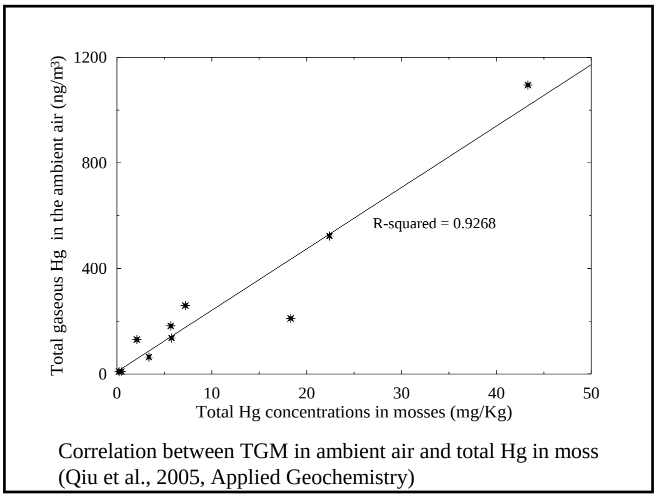

calcines-125.8 million tons
calcines piles
calcines combined with tailings piles


pH = 12; Total Hg=1310 ng/l
small villages
Irrigating water


Hg flux (ng m-2 h-1)
400
350
300
250
200
150
100
50
0
2002-11-23 6:00
2002-11-23 9:00
2002-11-23 12:00
2002-11-23 15:00
2002-11-23 18:00
Sampling time
Mercury emission flux from calcine

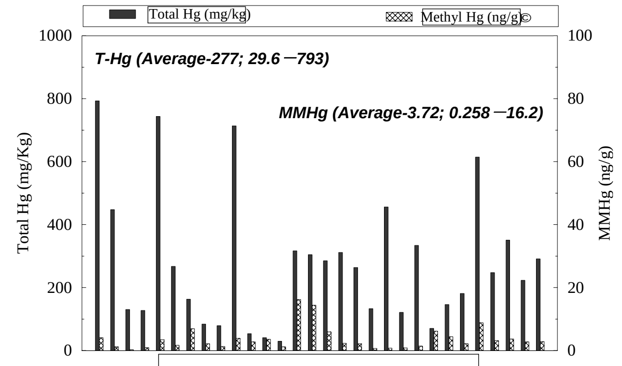

Mercury in moss in Hg mining areas
Total Hg (mg/kg)
MM Hg (ng/g)
T-Hg (Average-15.0; 0.538 —95.1)
MMHg (Average-4.27; 0.210 —21.4)
Total Hg (mg/Kg)
MMHg (ng/g)
100
80
60
40
20
0
Moss samples collected in Wanshan, Wuchaun and Lanmuchang Hg mining areas


Total gaseous Hg in the ambient air (ng/m3)
1200
800
400
0
R-squared = 0.9268
0
10
20
30
40
50
Total Hg concentrations in mosses (mg/Kg)
Correlation between TGM in ambient air and total Hg in moss (Qiu et al., 2005, Applied Geochemistry)

Mercury in surface water in Wanshan area (ng/l)

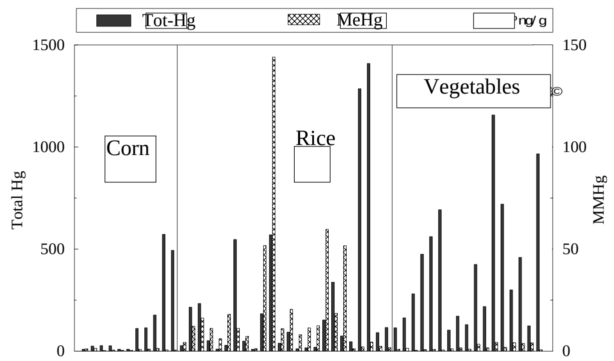
	Min	Max	Average	Background Value in Europe
Total Hg	15.3	4462	582	<5
Dissolved Hg	12.5	426	44.6	<1

Mercury in soil from Hg mining area



Soil samples collected from Wanshan, Wuchuang and Lanmuchang

Tot-Hg and MeHg in crops in Hg mining area



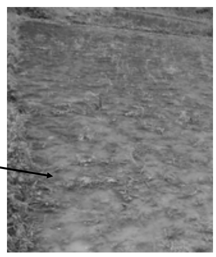
Samples collected in Wanshan, Wuchang and Lanmuchang mercury mining areas

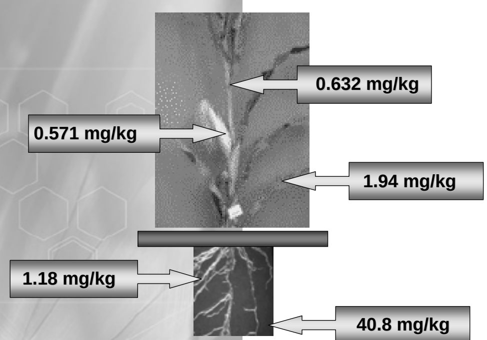
Summary of Hg concentrations in foodstaffs collected in mercury mine areas（in ng/g) (Qiu and Feng, Applied Geochemistry, 2005）

	Species	Min	Max	Mean	n	National advisory limit
Corn	Hg-tot	9.0	572	143	11	20
	MMHg	0.3	1.3	0.7		
Rice	Hg-tot	9.0	1408	234	25	
	MMHg	1.1	144	20.1		
Vegta-bles	Hg-tot	103	1156	415	17	10
	MMHg	0.4	4.2	1.9		

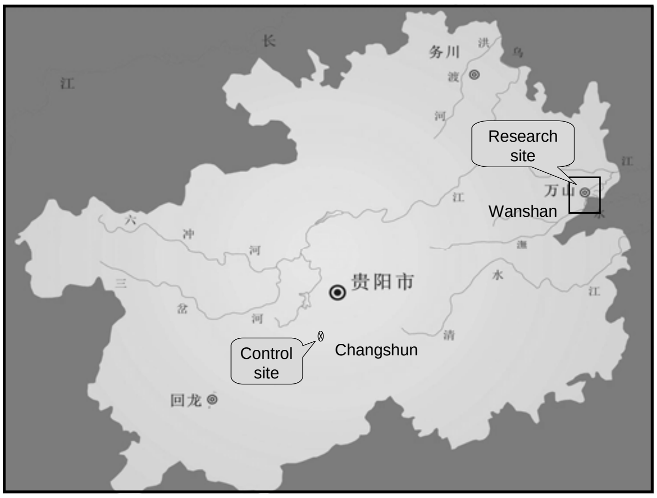
Methyl-Hg in paddy and cornfield soil samples from Hg mining areas in Guizhou (dry weight, μg·kg^{-1})

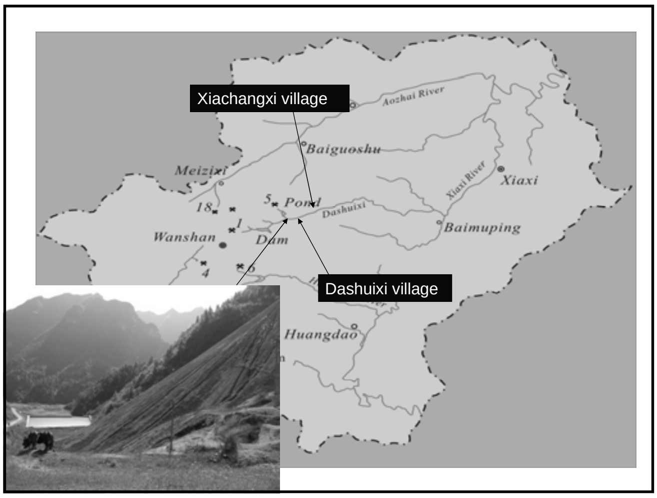
types	range conc.	mean conc.
cornfields	0.091-2.3	0.77
paddies	**1.0-20**	**4.4**

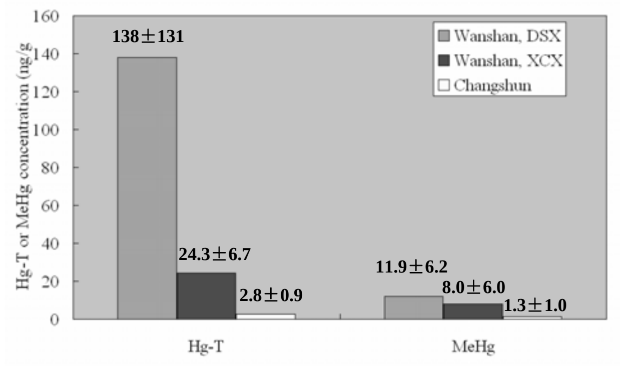




Total mercury distributions in different parts of a corn plant growing in Guizhou Hg mining areas

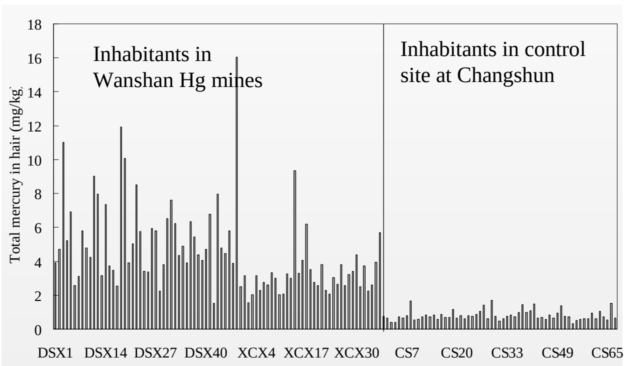


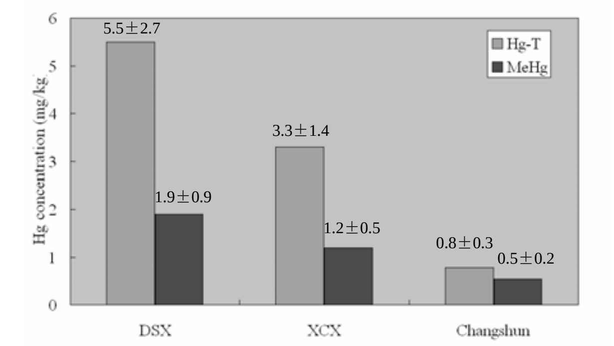




Mercury concentrations in rice samples collected at DSX, XCX village and the control site

Mercury in Hair samples collected from DSX and XCX villages in mercury mining areas and control site





Mercury in Hair samples collected from DSX and XCX villages in mercury mining areas and control site

$$C = \frac{d \times A \times f \times bw}{b \times V}$$ **(USEPA, 1997)**

d represents daily Me-Hg intake in μ g/d/kg;
A is the absorption factor which is assumed to be 0.95;
f is the absorbed dose found in blood;
bw is the body weight (60 kg);
b is the elimination constant (0.014);
V is the blood volume (5L)

the hair: blood concentration ratio is frequently cited as 250:1 expressed as μg /g hair Hg to μg /L of blood Hg

Daily Me-Hg intakes from rice and estimated and measured hair Me-Hg concentrations for residents in DSX and XCX villages in Hg mining areas

Site	Daily MeHg intake/ $\mu g \cdot d^{-1} \cdot kg^{-1}$	Modeled Hair MeHg/$\mu g \cdot g^{-1}$	Measured Hair MeHg/$\mu g \cdot g^{-1}$
DSX	**0.119**	**1.43**	**1.9**
XCX	**0.080**	**0.96**	**1.2**

The US Environmental Protection Agency (USEPA) recommended guideline values for Me-Hg in the diet that is 0.1 μg/kg/day

Outline

- **Mercury contamination to the local environment from historical large scale Hg mining activities and health impacts to local inhabitants**
- **Mercury contamination to the local environment from current small scale Hg smelting activities and health impacts to miners**

Artisanal mercury smelting in Wuchuang, Guizhou

Smelting residues

$$F = \frac{(O - S) * W * 10^{-6} - P}{P} * 100\%$$

F: mercury emission factor (%)

O: Hg concentration in ore (mg/kg)

S: Hg concentration in calcine (mg/kg)

W: Total consumption of Hg ore per day (kg)

P: Daily mercury production (kg)

Mercury emission factors in different mining areas in Wuchuan

Site	O (mg/kg)	S (mg/kg)	W (kg)	P (kg)	F (%)
YQG	6135	12	270	1.25-1.5	10.2-32.3
LX	3665	118	270	0.75-0.85	12.7-22.7
TB	1667	7	270	0.35-0.4	12-28
Average					20.5

Annual Hg emission in Wuchuan Hg-mining areas

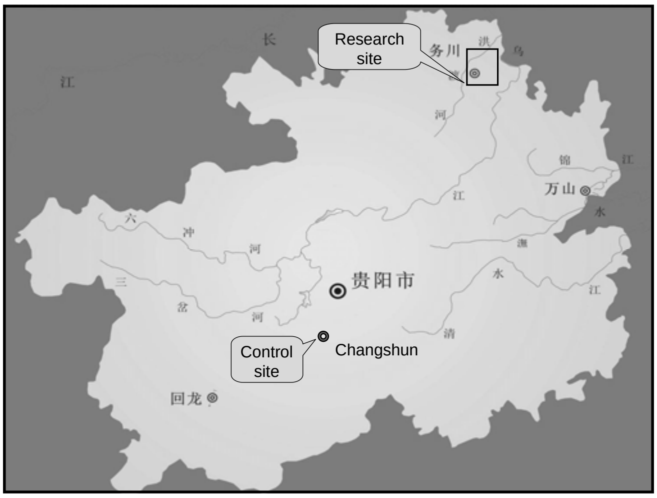
Site	YQG	LX	TB	Total
Number of furnaces	70	10	25	105
Annual Hg production (t)	26.2-31.5	2.3-2.6	2.6-3.0	31.1-37.1
Annual Hg emission (t)	3.2-8.5	0.3-0.6	0.4-0.7	**3.9-9.8**

Hg distribution in surface water of Wuchun Hg mining areas (in ng/l)

	Min	Max	Average	n
Hg-tot	22.1	362.0	141.0	14
MeHg	0.21	5.7	1.45	14

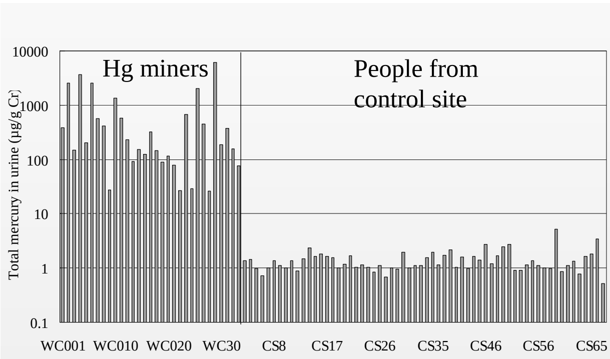
Distribution of Hg in soil and calcines in Wuchan Hg mining areas

	Hg-tot (μ g/g)	MeHg (ng/g)
Soils	0.33 – 317	0.69 – 20
Calcines	79 – 714	0.32 – 3.9
Baselines	0.18 – 0.40	0.09 – 0.23

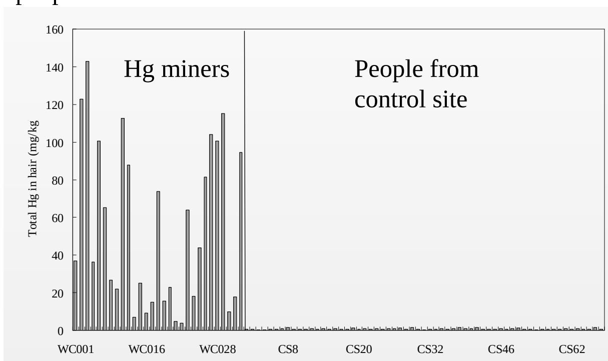


Total gaseous Hg concentrations in the ambient air were up to 40 μ g/m^3 (N=10) near the smelting furnace, which exceeded the Chinese occupational criteria limit value (10 μ g/m^3).

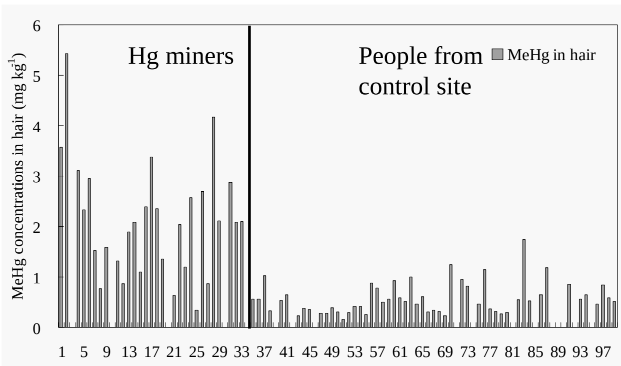
Total mercury concentrations in urine of Hg miners and people from control sites

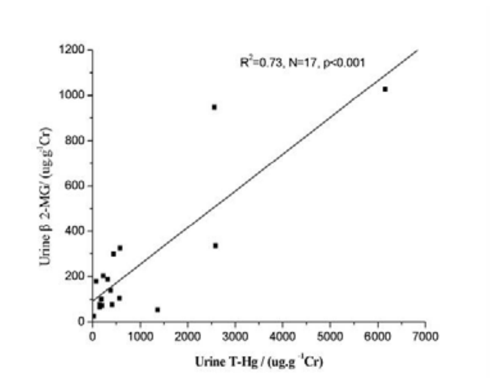


Total mercury concentrations in hair of Hg miners and people from control sites



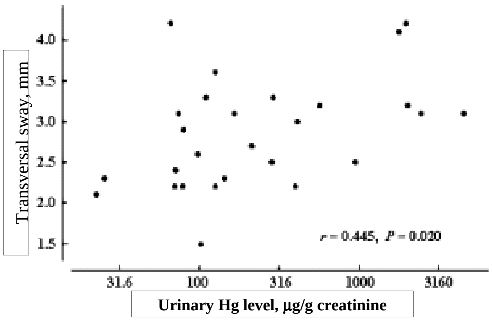
MeHg concentrations in hair of Hg miners and people from control sites





Difference (mean±SD) in tremor intensity between 27 Hg exposed workers and 52 unexposed subjects (m/s²) (Iwata et al., 2006)

Frequency (Hz)	Exposed workers	Control subjects	P values
Dominant hand Total	**0.234±0.111**	0.172±0.077	0.006
1-6	**0.090±0.038**	0.071±0.019	0.004
6-10	**0.160±0.063**	0.143±0.063	0.258
10-14	**0.112±0.076**	0.071±0.051	0.007
Non-dominant hand Total	**0.209±0.111**	0.143±0.054	0.001
1-6	**0.085±0.027**	0.073±0.019	0.027
6-10	**0.123±0.053**	0.109±0.056	0.290
10-14	**0.108±0.077**	0.060±0.029	<0.001



Correlation between log-transformed urinary Hg level (μg/g Cre) and transversal sway (mm) of postural sway test with eyes open in 27 Hg exposed workers (Iwata et al., 2006 in press)

Main Conclusions

- Historic mine tailings and calcines from large scale Hg mining activities are definitely the major Hg contamination source to the local environment in Hg mining areas.
- Rice paddy may serve as an important methylating site for Hg. Rice could accumulate MeHg from Hg contaminated soil. We demonstrated that eating rice is the major pathway of MeHg exposure to the local inhabitants in mercury mining areas, posing threat to the health of local community. This finding was an important supplement for the general viewpoint that human exposed to Me-Hg was primarily through the intake of fish or fish products.

Main Conclusions

- Current artisanal Hg smelting activities have resulted in serious Hg contamination to the ambient air, surface water and soil compartments in the local environment.
- Mercury vapor exposure is a major concern to the Hg smelting workers and local inhabitants in current artisanal Hg smelting areas. Our study showed that a serious adverse effect on renal system and postural sway, as well as hand tremor, to the Hg smelting workers due to high level exposure to elemental Hg vapor.

Ninth International Conference on Mercury as a Global Pollutant will be held in July 2009, Guiyang, China

Acknowledgment

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Effects of Mercury Vapor Exposure on Neuromotor Function in Chinese Miners and Smelters

Toyoto Iwata[1], Mineshi Sakamoto[2], Xinbin Feng[3], Minoru Yoshida[4], Xiao-Jie Liu[2], Miwako Dakeishi[1], Ping Li[3], Guangle Qiu[3], Hongmei Jiang[3], Masaaki Nakamura[2], Katsuyuki Murata[1]

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[4] Faculty of Human Health Science, Hachinohe University

Objectives Current risk assessment of elemental mercury vapor is based on the tremor toxicity. To clarify the neuromotor effects of occupational exposure to mercury vapor, hand tremor and postural sway were measured in 27 miners and smelters (i.e., exposed workers) and 52 unexposed subjects.

Methods Urine samples were collected and total mercury and creatinine concentrations were determined. Data of the tremor and postural sway were analysed using the fast Fourier transformation.

Results The geometric means of the urinary mercury level (UHg) were 228 (range 22.6-4,577) μg/g creatinine for the exposed workers and 2.6 (1.0-17.4) μg/g creatinine for the unexposed subjects. Total tremor intensity and frequency-specific tremor intensities at 1-6 and 10-14 Hz were significantly larger in the exposed workers than in the unexposed subjects ($P < 0.05$), but they were not significantly related to the UHg among the exposed workers ($P > 0.05$). In contrast, there were no significant differences in any postural sway parameters between the above two groups ($P > 0.05$), but the transversal sway with eyes open was positively related to the UHg among the exposed workers in using multiple regression analysis ($P < 0.05$).

Conclusions These findings suggest that postural sway, as well as hand tremor, may be affected by elemental mercury vapor exposure, but the former test seems to be less sensitive to mercury than the latter one.

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Effects of mercury vapor exposure on neuromotor function in Chinese miners and smelters

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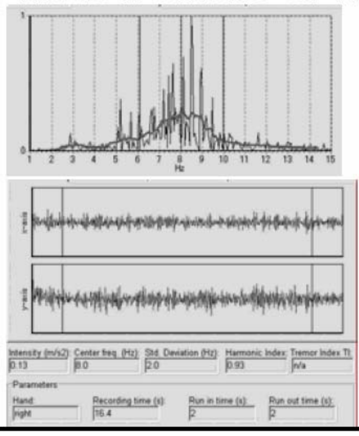
1. Clinical symptoms of mercury vapor intoxication
2. Measurement of hand tremor
3. Measurement of postural sway
4. Results of the cross-sectional study
5. Conclusion

Clinical symptoms of mercury vapor poisoning

Substance (compounds)	Oxidation number		Symptoms
Hg	0	Metallic (vapor)	Kidney damage, Tremor, Adiadochokinesis, Inflammation of the gums, Fatigue, Impaired memory, Irritablity
HgCl	1	Inorganic (ions)	
$HgCl_2$	2		
$HgCH_3$	1	Organic	Concentric constriction of visual fields, Hearing loss, Tremor, Cerebellar incoordination, Sensory impairment

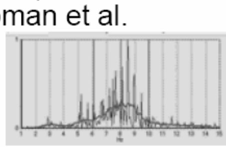
Measurement of hand tremor



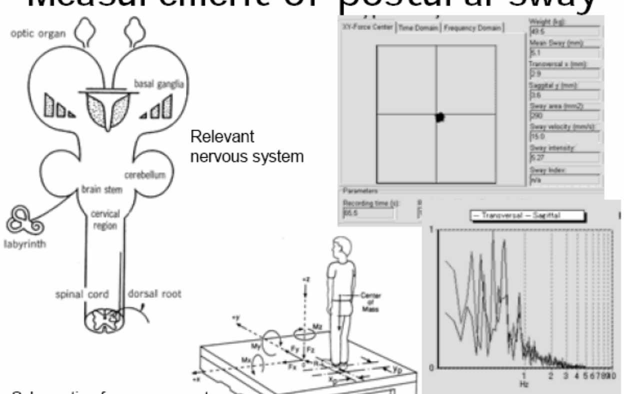
Significance of hand tremor

US Agency for Toxic Substances and Disease Registry (ATSDR) derived *Minimal Risk Level* (MRL) for mercury vapor according to tremor study (Fawer et al. 1983).

Increase in tremor is reported at 6.6-10 Hz (Biernat et al. 1999), 8-12 Hz (Verberk et al. 1986), and 10-15 Hz (Chapman et al. 1990).



Measurement of postural sway



Schematic of measurement set-up (Sack et al.)

Subjects

- 27 male miners/smelters of small-scale mining sites in south-western China
- 52 age-matched male controls dwelling in the same region and having resembling life styles (farmers, construction workers, and office clerks)

Smelting sites

Methods

- Urinary mercury (μg Hg/g Creatinine)
  Spot urine samples were collected on the day of testing
- Tremor for each of right and left hands, with use of frequency analysis
- Postural sway with eyes open and closed, with use of frequency analysis

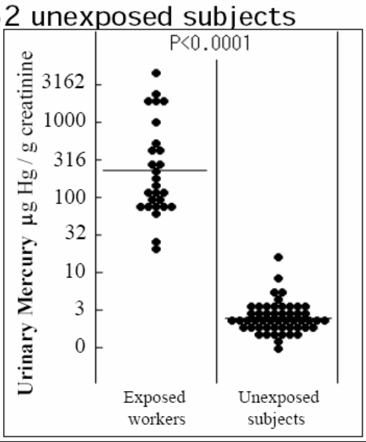
Characteristics of mercury-exposed workers and unexposed subjects

(mean±SD or number (%))

	27 exposed workers	52 unexposed subjects	*P* *
Age (years)	41 ± 10	39 ± 13	0.459
Height (cm)	162 ± 8	162 ± 5	0.835
Education (years)	5.6 ± 3.5	6.0 ± 4.2	0.710
Drinker	12 (44)	31 (60)	0.238
Smoker	23 (85)	39 (75)	0.392

* Student *t* test or Fisher exact test

Urinary mercury of 27 mercury-exposed workers and 52 unexposed subjects



Differences in tremor intensities (m/s^2, mean±SD) between mercury-exposed workers and unexposed subjects*

	27 exposed workers	52 unexposed subjects	*P*
Dominant hand (Hz)			
1-15	0.234 ± 0.111	0.172 ± 0.077	0.006
1-6	0.090 ± 0.038	0.071 ± 0.019	0.004
6-10	0.160 ± 0.063	0.143 ± 0.063	0.258
10-14	0.112 ± 0.076	0.071 ± 0.051	0.007
Non-dominant hand (Hz)			
1-15	0.209 ± 0.111	0.143 ± 0.054	0.001
1-6	0.085 ± 0.027	0.073 ± 0.019	0.027
6-10	0.123 ± 0.053	0.109 ± 0.056	0.290
10-14	0.108 ± 0.077	0.060 ± 0.029	<0.001

* Analysis of covariance was used to control for age, height, and drinking and smoking status

Differences (mean±SD) in postural sway parameters between mercury-exposed workers and unexposed subjects*

	27 exposed workers	52 unexposed subjects	P
Eyes open			
Sway area (mm^2)	224 ± 112	204 ± 78	0.382
Transversal sway (Dx, mm)	2.83 ± 0.69	2.89 ± 0.87	0.783
Dx 0-1 Hz	3.52 ± 0.88	3.56 ± 1.03	0.890
Dx 1-2 Hz	0.47 ± 0.20	0.46 ± 0.15	0.802
Dx 2-4 Hz	0.17 ± 0.07	0.18 ± 0.06	0.448
Sagittal sway (Dy, mm)	3.11 ± 0.92	3.53 ± 1.20	0.136
Dy 0-1 Hz	3.92 ± 1.14	4.32 ± 1.41	0.220
Dy 1-2 Hz	0.49 ± 0.17	0.45 ± 0.12	0.246
Dy 2-4 Hz	0.22 ± 0.06	0.23 ± 0.07	0.656
Eyes closed			
Sway area (mm^2)	346 ± 180	318 ± 182	0.529
Transversal sway (Dx, mm)	3.40 ± 1.08	3.12 ± 0.96	0.268
Dx 0-1 Hz	4.22 ± 1.32	3.83 ± 1.17	0.204
Dx 1-2 Hz	0.71 ± 0.25	0.75 ± 0.33	0.581
Dx 2-4 Hz	0.26 ± 0.08	0.27 ± 0.11	0.734
Sagittal sway (Dy, mm)	3.43 ± 0.78	3.58 ± 1.32	0.607
Dy 0-1 Hz	4.26 ± 1.04	4.38 ± 1.59	0.729
Dy 1-2 Hz	0.76 ± 0.26	0.72 ± 0.31	0.613
Dy 2-4 Hz	0.33 ± 0.11	0.35 ± 0.16	0.555

* Analysis of covariance was used to control for age, height, and drinking and smoking status

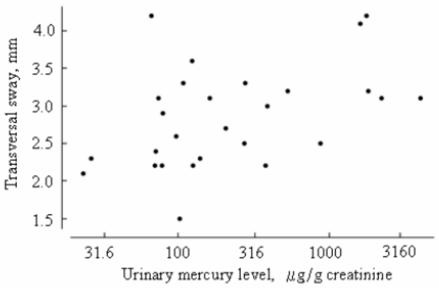
Relations of neuromotor function parameters to urinary mercury ($\log_{10}$[UHg]) in 27 mercury-exposed workers

		β
Tremor intensity (m/s^2)		
Dominant hand	1-15 Hz	−0.348
	1-6 Hz	−0.147
	6-10 Hz	−0.244
	10-14 Hz	−0.379
Non-dominant hand	1-15 Hz	−0.183
	1-6 Hz	−0.066
	6-10 Hz	0.004
	10-14 Hz	−0.232
Postural sway		
Eyes open		
Sway area (mm^2)		0.173
Transversal sway (Dx, mm)		**0.502**
Dx 0-1 Hz		**0.496**
Dx 1-2 Hz		−0.074
Dx 2-4 Hz		−0.031
Sagittal sway (Dy, mm)		−0.070
Dy 0-1 Hz		−0.071
Dy 1-2 Hz		−0.242
Dy 2-4 Hz		−0.140
Eyes closed		
Sway area (mm^2)		0.196
Transversal sway (Dx, mm)		0.356
Dx 0-1 Hz		0.346
Dx 1-2 Hz		−0.092
Dx 2-4 Hz		−0.076
Sagittal sway (Dy, mm)		−0.013
Dy 0-1 Hz		−0.019
Dy 1-2 Hz		−0.047
Dy 2-4 Hz		0.064

β standardized regression coefficients for $\log_{10}$[UHg] in the multiple regression analysis with $\log_{10}$[UHg], age, height, and drinking and smoking status as independent variables

Expressed in red where $p < 0.05$

Correlation between urinary mercury level and transversal sway with eyes open in 27 mercury-exposed workers



r = 0.445, p = 0.020

Discussion 1

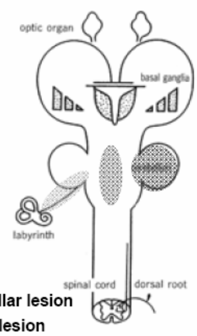
1. Urinary mercury and hand tremor intensity were increased in the 27 mercury-exposed workers, as compared to the 52 unexposed subjects
2. Tremor intensities at 1-6 and 10-14 Hz were significantly increased in both hands.

   Increase of tremor intensity at 10-14 Hz was accordant with previous findings.

Discussion 2

3. Among the 27 exposed workers, urinary mercury ($\log_{10}$[UHg]) was significantly, but not so strongly, related to transversal sway with eyes open.

   Among postural instability patterns by cerebellar lesions (Araki et al. *Am J Ind Med*, 2000), the vestibulocerebellar lesion seems most relevant to mercury vapor.

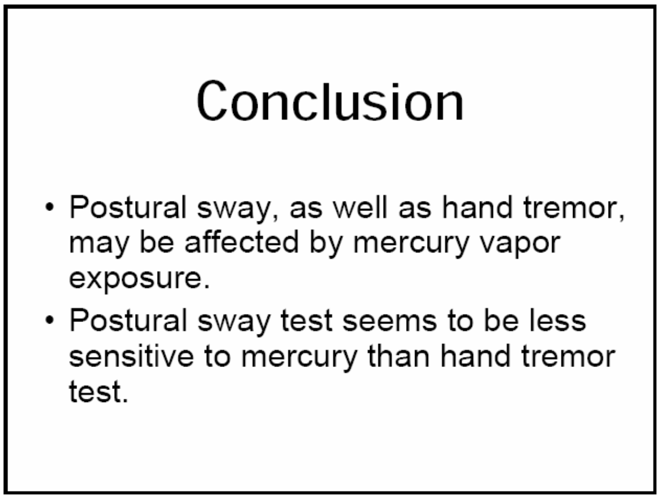


Vestibulocerebellar lesion
Spinocerebellar lesion
Anterior cerebellar lobe lesion

Discussion 3

4. The lowest-observed-adverse-effect level of mercury affecting hand tremor (Fawer et al. 1983), from which ATSDR derived the *Minimal Risk Level*, was around 20 μg/g Cre.

   By contrast, critical concentration (BMDL, 95% lower confidence limit of Benchmark Dose) estimated from data of the postural sway was 406 μg/g Cre. In this sense, the postural sway test may not be a sensitive method for the neurotoxic assessment of mercury vapor.


Conclusion
• Postural sway, as well as hand tremor, may be affected by mercury vapor exposure.
• Postural sway test seems to be less sensitive to mercury than hand tremor test.

Case Report on the Mercury Spill Incident in a Private School in Manila, Philippines: Actions Taken and Lessons Learned*

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Department of Health, Manila, Philippines

Abstract

On February 19, 2006, the UP-National Poisons Management and Control Center (UP-NPMCC) at the Philippine General Hospital in Manila received a call from a grandparent regarding his grandson, a 14 y/o male presented with numbness, redness, pain of extremities with history of exposure to elemental mercury. The toxicologist on duty was informed that a mercury spill occurred in the science class in the morning and another incident happened in the afternoon in another class. 80 Grade 7 students ages 13-14 years old and the Science teacher from two classes were exposed to elemental mercury. The children reportedly applied mercury on their skin, hair and other parts of the body. Some even brought some mercury samples to their homes as souvenirs. The UP-NPMCC alerted concerned government agencies and coordinated with the school authorities to elicit additional information on the incident.

Based on the report by clinical toxicologists, the primary mode of exposure were dermal and inhalational. Signs and symptoms of acute mercury exposure were seen by clinical toxicologists, The Environment Department reported that based on their documentation, the total mercury spilled can be estimated at 326.4 g - 408 g (March 24,2006). However, interviews with the affected students gave different accounts than what was officially reported.

Initial monitoring done showed ambient air mercury levels were >100 ug/m3 (exceeding the NIOSH ceiling limit) in the 3 contaminated classrooms. Laboratory tests using cold vapor atomic absorption spectrophotometry method revealed levels ranging from 8–112 ug/m3 exceeding the minimal risk level (MRL) for mercury at 0.2 ug/m3 set by the Agency for Toxic Substances and Disease Registry (ATSDR). Follow-up monitoring revealed mercury levels of as high as 525 ug/m3 in one of the contaminated classrooms. Technical assistance from US-Environmental Protection Agency (USEPA) was requested to assist in the clean-up and remediation efforts.

This paper outlined the efforts made by the Inter-Agency Committee on Environmental Health (IACEH) which is composed of 12 national line agencies, representatives from the academe and chaired by the Department of Health. A series of meetings were conducted to address and resolve these issues and problems. IACEH resolutions included health, environmental clean-up measures

* *Collated from the IACEH reports and resolutions, DOH, OSHC-DOLE, UP-NPMCC, EMB-DENR and Globecare reports*

and policy recommendations have been promulgated for implementation by the different concerned agencies and stakeholders to harmonize and streamline all efforts/actions to implement coordinated. and appropriate strategic public health and technically acceptable environmental interventions to protect the health of the schoolchildren, faculty and other sectors of the population and the environment. Proceedings of these meetings have been transparent and participative in nature to ensure that all sectors including the school authorities have been consulted in the decision-making process.

Introduction:

On February 19, 2006 (Sunday) the UP-National Poisons Management and Control Center (UP-NPMCC) at the Philippine General Hospital in Manila received a call from a grandparent regarding his grandson, a 14 y/o male presented with numbness, redness, pain of extremities with history of exposure to elemental mercury on February 16, 2006. The toxicologist on duty was informed that a mercury spill occurred in the science class in the morning and another incident happened in the afternoon in another class. The school authorities were not informed of the incident. The UP-NPMCC alerted the Department of Emergency Medical Services at PGH, the Health Emergency Management Staff of the Department of Health and the Environmental Management Bureau (EMB) of the Department of Environment and Natural Resources (DENR). The UP-NPMCC coordinated with the school authorities to elicit additional information on the incident. During the weekend, the school janitor did his usual cleaning chores and used a floor polisher to clean the room. Floor polishing aggravated the dispersion of mercury into the environment. Construction was on-going near the classrooms. A market, church and a public school are located adjacent to the site.

The school provides pre-school, elementary and secondary education with a total population of 2,364 students and 140 faculty/support staff.

The following day government teams were sent into the school to conduct investigations. Interviews with the teacher and the students initially provided information that 2 beakers filled with an estimated 100 – 200 grams of mercury were spilled in the science class in the morning and the afternoon. The EMB-NCR reported that based on their documentation, the total mercury spilled can be estimated at 326.4 g - 408 g (March 24, 2006 EMB-NCR report). However, based on interviews with the affected students gave different accounts than what was officially reported. According to accounts from the school authorities and the students revealed that the teacher was writing the lessons on the board when the children, mostly boys played with the beaker and spilled some mercury in the room. The children reportedly applied mercury on their skin, hair and other parts of the body. Some even brought some mercury samples to their homes as souvenirs.

The Inter-Agency Committee on Environmental Health (IACEH) which is composed of 14 national line agencies and chaired by the Department of Health had regularly meetings to address and resolve health, environment, education and other concerns that were brought about by the mercury spill in the school. Proceedings of these meetings have been transparent and participative in nature to ensure that all sectors including the school representatives have been consulted in the decision-making process

Health Assessment and Monitoring:

Based on the UP-NPMCC report, on February 16, 2006 in the morning , 80 students, Grade 7, ages 13-14 years old and the Science teacher from St. Ambrose and St. Francis de Sales sections exposed to elemental mercury. The primary mode of exposure were dermal and inhalational routes. Initially, 10 students were admitted at PGH because of fever, rashes (erythematous papules, pinpoint), difficulty of breathing, chest pain and body malaise. Impression of the clinical toxicologists was acute mercury inhalation with systemic contact dermatitis.

Management was supportive mainly provision of fluids and control of fever. Referral was also made to Dermatology service for a skin biopsy to be done. In the next few days (February 20-24) 2 students were admitted at a private hospital for the same complaints. 12 more students were admitted at the PGH, for the period of February 23 - February 28, 2006, this time because of high grade fever (12), rash (8), body pains (3), difficulty of breathing (2), diarrhea (2), dysphagia (2), nausea / vomiting (1). Management was mainly supportive: Fluids, control of fever, Diphenhydramine and Oxygen inhalation. Onset of symptoms among the twenty four (24) students who were initially admitted at the hospital was 13-16 hours post-exposure.

The main signs and symptoms were as follows:

Headache	57.0%	Fever	26.0%	Numbness	8.5%
Pruritus	41.9%	Cough/colds	23.6%	Redness/swelling of upper extr.	4.3%
Dyspnea	36.6%	Chest pain	20.4%		
Weakness	35.5%	Muscle pain	17.2%		
Dizziness	34.4%	Nausea	16.1%		

Inter-Agency Committee on Environmental Health (IACEH) Action:

The chief epidemiologist of the Department of Health called up the environmental and occupational health team (consisting of the Environmental and Occupational Health Office-National Center for Disease Prevention and Control, the National Center for Health Facility Development, the UP-NPMCC and the academe, the UP-Department of Pharmacology and Toxicology) on the evening of February 20, 2006 who were in Sorsogon about 600 kilometers south of Manila at that time, conducting a health assessment of a community affected by a mining spill and requested technical information and advice from the team. The regional epidemiologist also made a similar request from the team. Initial information provided was that 12 children were hospitalized and that the rooms' air-conditioning system was centralized. No ambient air monitoring data was available including the amount of mercury spilled at that time. Technical advice was given to cordon off the area where the spill occurred. The chief epidemiologist also asked if it would be prudent to suspend classes to make a more thorough assessment of the area. The group agreed to this recommendation.

The next day, coordination was made with EMB-DENR for the conduct of air monitoring. However, the agency has no technical capability/equipment to monitor for ambient air mercury. In view of this, the Occupational Safety and Health Center (OSHC) of the Department of Labor and Employment was requested to do the mercury monitoring. Coordination was likewise made with the Special Rescue Unit from the Bureau of Fire Protection who were trained and equipped with chemical protective equipment and sampling devices. An inter-agency collaboration for a rapid environmental assessment was planned upon the return of the team to Manila the following day.

On February 22, 2006, the chief epidemiologist convened the inter-agency group. Information revealed that there were three (3) classrooms which were mainly affected, Rooms 129, 130 and 131. A floor plan of the classrooms was provided. An inventory of the resources was made. The Department of Health had 6 pieces of detector tubes for mercury determination was available. No other real time-direct reading device was available.

The team were grouped into three (3) units who will conduct sampling of the classrooms in the five (5) storey building. An initial 2-man team would make a rapid assessment of the three (3) affected classrooms at the ground floor for mercury levels using the grab samples. For safety reasons, the initial team wore Level "B" suits because of the lack of information regarding the mercury levels in the room The entry of the second and third teams depended on the results of the initial entry. .However, entry of additional personnel for the expanded sampling would depend on the results of the initial entry. It was agreed upon that the sampling would proceed if the results would be less than 100 ug/m^3 which is the ceiling concentration set by NIOSH. Ceiling levels were defined as the concentration of mercury that should not be reached at any given time.

The SRU made an evaluation of the predominant wind direction which was noted to be prevailing towards the church area and variable as time progresses. Decontamination zone was set-up at the parking area within the school premises. All non-essential items were left at the conference room to avoid contamination. Thus, there was no means of communication between the management and the hazmat team. Entry of the initial team was stalled for around thirty (30) minutes until such time that permission from the school authorities to enter the school premises was confirmed. Keys to the room were also provided to the team. The team initially expected that the set-up of the rooms would be similar to a laboratory. However, the room set-up was the usual classroom arrangement. The team noted that air-conditioning units were installed in the ceilings and noted that there were visible mercury beads in the crevices in the floors.

The rapid environmental tests using the Draeger sampler showed mercury levels at > 100 ug/m3 for the three rooms. Swipe samples of floor and walls were also collected using alcohol-free wipes. The team reported back the results to the group. It was decided that only the SRU unit will set-up the air sampling equipment of the OSHC in the three rooms. Sampling time was for 10 minutes using the liquid absorption technique with a Hiranuma mercury analyzer. Environmental monitoring of ambient air in the three classrooms and the surrounding areas using reduction atomization absorption method revealed levels ranging from 8 – 112 ug/m3. These results were elevated when compared with the minimal risk level (MRL) for mercury at 0.2 ug/m3 set by the Agency for Toxic Substances and Disease Registry (ATSDR) of the United States. Minimal risk levels are defined as estimates of daily human exposure to a chemical that is likely to be without an appreciable risk of harmful effects over a specified duration of exposure. For chronic exposures, the US Environmental Protection Agency has set a reference concentration for chronic inhalation exposure RfC of 0.3 ug/m3. Swipe wall and floor samples showed levels of mercury at 0.29 – 10.98 ug/g

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INITIAL MERCURY DETERMINATION IN AMBIENT AIR

Areas Monitored	Initial Entry Levels (ug/m3) DIRECT RDG.)	Ambient/Room concentration (ug/m3) - Laboratory	Swipe samples (ug/g) Laboratory
Guard station nearMain gate (about 50 ft from the garage)	**-**	**15**	**-**
Room 129	**>100**	**11**	**Wall – 0.29; Floor – 0.31**
Room 130	**>100**	**112**	**Wall – 0.31 Floor- 10.98**
Room 131	**>100**	**68**	**Wall – 0.72 Floor – 9.20**
Garage area about 6 meters from gate of classroom	**-**	**11**	**-**
Among street fronting main gate of the school	**-**	**8**	**-**

Based on the sampling results, classes remain suspended upon the recommendation of the DOH to DepEd. An advisory to the schools on the use of mercury was developed by DOH. A copy was provided to the Dep-Ed for dissemination to all schools. The Inter-Agency Committee on Environmental Health (IACEH) was convened on February 28, 2006 to determine the next steps and way forward. An update of the activities undertaken were discussed. It was evident that there were no existing guidelines on how to do mercury clean-up in schools and which agency will take charge/lead in the clean-up. Issues discussed included the appropriate standards (environmental, occupational, MRL, RfC, etc), agency responsible for the clean-up and disposal of wastes. to be adopted Two (2) service facility providers made a presentation on their proposal for clean-up. The EMB-DENR reported that a team an initial investigation on 21 February, 2006 A notice of violation (Section 7 of DAO 97-38) for non-registration in the use of mercury was sent to the School Principal. Fines and charges will be leveled against the school for non-compliance. EMB informed that all users of mercury should register with the agency by virtue of the Chemical Control Order on Mercury. The IACEH resolution No. 001-2006 dated March 01, 2006 called for the immediate clean-up of mercury. No clean-up facility was recommended because of some technical deficiencies in the presentation of the service provider.

The IACEH also considered that the exposed population were mostly children (i.e. students) who are vulnerable to contaminants because they are more likely to come into contact with dusts, soil, and heavy vapors close to the ground. Children also receive, higher doses of chemical exposure due to lower body weights. The clinical toxicologists recommended the standards set by the Agency for Toxic Substances and Disease Registry (ATSDR, USA) for the Minimal Risk Level MRL) of mercury of 0.2 ug/m3. It was also emphasized that mercury per se is not beneficial to the human body and thus should not be present especially among children.

While the team did not have any information on the possible background levels of mercury in the area. Current references discussed that globally, background levels of mercury is 0.01 – 0.02 ug/m3 in the ambient air. Background levels in nonurban settings are even lower generally 6 ng/m3 of less. With the results showing mercury levels in the streets, there was a good indication that mercury was spread into the area through dispersion into the environment brought about by the movement/tracking of people with contaminated clothing/shoes.

Case studies currently available showed that mercury signs and symptoms can be seen even after more than 25 days of exposure. It should be emphasized that non-detectable levels of mercury in the blood does not mean that no exposure occurred but rather the biomarker used did not reflect the exposure. In this case, urine mercury level is the recommended biomarker.

During the meeting two (2) service providers for the mercury clean-up, presented the proposed clean-up activities. The first service provider proposes to use activated carbon to bind the mercury.

Mercury vacuum cleaners would also be used to sweep visible mercury beads in the classroom. Real time monitoring using a lumex would be done prior to and after the clean-up. Costs for the clean-up of the three classrooms would amount to $7,000.00 (1$=P50). Equipment and other materials to be used would be brought in from its mother company abroad. However, disposal of wastes would not be part of the package proposal.

The second company proposes to use insolubilization and amalgamation techniques to bind the mercury. Package would include disposal of wastes generated from the clean-up to a DENR accredited facility. Real-time monitoring of mercury levels would also be done in other areas which may be contaminated with mercury (e.g. library, etc). Water samples from the construction site adjacent to the classrooms would also be tested. Post clean-up tests and monitoring would also be done. Costs estimates proposed by the private company was P915,000.00.

Information provided to the IACEH revealed that the school signed-up the second service provider of the company for the clean-up on March 01, 2006. Clean-up was done on March 4-6, 2006. . No real time monitoring was done and the service provider borrowed air sampling device (s) from the for the clean-up operations informing them that their supplies were not yet available and clean-up activity was already scheduled The DOH acceded to the request of the company in view of the IACEH resolution. On March 06, 2006, a staff from the EOHO-NCDPC/DOH conducted air sampling monitoring for the post-clean-up. A parallel and independent post-sampling was done on March 10, 2006 by the first team that conducted the initial sampling. On inspection, mercury beads were still visible in the crevices/floor.

Results of the post-clean up monitoring were as follows;

Areas Monitored	Ambient Concentration of Mercury, mg/m³		
	Before Clean-up	After Clean-up	
	22 Feb 2006 (OSHC)	6 Mar 2006 (CHEMPRO)	10 Mar 2006 (OSHC)
At garage area about 6 meters from gate of classroom	0.011	-	bdl
Guard station near main gate	0.015	-	bdl
Along street fronting main gate	0.008	-	bdl
Gate	-	0.00012	-
Room 131 (1.5 m height)	0.068	0.00237	0.0075
Room 130 (1.5 m height)	0.112	0.00032	0.045
Room 129 (1.5 m height)	0.011	0.00083	bdl
Room 131 (below 1.5 m height)	-	-	0.0075
Room 130 (below 1.5 m height)	-	-	0.0075
Room 129 (below 1.5 m height)	-	-	bdl
Library	-	-	bdl
Hallway / Passageway		0.00881	-

*bdl = below detection limit

The Library at the 3rd floor where the children were examined have floor and wall Hg levels of 0.07 ug/g (March 10, 2006 independent post-sampling result). The results confirmed the initial hypothesis that since no decontamination was made, mercury tracking from the shoes and clothes among the students may have further dispersed the mercury into the other areas in the building. IACEH Resolution No. 0002 took note of the fact that some provisions as stipulated in the service provider's proposal were not followed. There was non-adherence to standard procedures for the clean-up action of mercury spills, inadequacy of proper personal protective equipment, a real time mercury vapor analyzer to ascertain the reduction in levels as the clean-up work progressed was not used, lack of observance of health and safety measures, and use of equipment not previously stipulated in the proposal submitted to the school. The DOH also sent a letter to the clean-up company requesting for a detailed report of the clean-up dated March 21, 2006. The IACEH resolution further resolved that the service provider will not proceed with the clean-up activity until they present a step by step clean-up procedure to be approved by the inter-agency. The service provider was also asked to submit list and certifications of all their HAZMAT technicians and an inventory, description and specification of their clean-up and monitoring equipment. The school was also asked to consider other service providers.

During the IACEH meetings, the recommended exposure guidelines to be adopted for the school and the clean-up methodology became the subject of heated discussions among the agencies. Representatives from the environment and labor agencies were recommending the NIOSH standards to be adopted at 0.05 mg/m3. However, the clinical toxicologists explained that the recommended guidelines were recommended for occupational exposure, the premise of which is that the workers are adults, duly informed of the risks to their occupation, provided with the appropriate personal protective equipment (PPE), adequate environmental engineering controls are in-place in the workplace and medical surveillance activities are implemented. The calculations made by the USEPA with regards to the Chronic Inhalation Reference Concentration (RfC for chronic inhalation) of 0.3 ug/m3, the ATSDR of 1 ug/m3 and the TLVs were based on the data obtained from the same studies where the lowest observeable adverse effect levels (LOAEL) were established. Based on epidemiological studies available, workers were found to have tremors after long-term exposure to mercury; The LOAEL level factored in an uncertainty factor of 10 was included to protect children and pregnant as well additional UF for the lack of data on cancer to establish the level of 0.3 ug/m3.

FOLLOW-UP ACTIVITIES:

HEALTH MONITORING/ASSESSMENT:

On February 20, 2006, 106 students/faculty were screened at the library and the church premises for possible exposure and adverse health effects to mercury. 97 people underwent evaluation on February 21-22, 2006 to include collection of blood and urine samples for mercury determination. Blood mercury levels showed that 35 (36%) out of the 98 individuals had detectable levels of blood mercury. Levels ranged from 0.10 ug/dl to 1.46 ug/dl. Thirteen (12 male students and 1 female teacher) individuals had levels higher than 0.75 ug/dl, which was the recommended guideline value. They underwent further evaluation (neurologic examination) which revealed sensory and motor deficits in 7 patients on electromyography nerve conduction velocity testing. Repeat blood mercury (March 3, 2006) showed non-detectable levels except for 2 patients. Urine mercury on 21 students (March 3, 2006) showed levels below 20 ug/L except for 1 student. On March 15, 2006: 5 students were followed-up with neurologic complaints: tremors and sensory deficits. Clinical toxicologists recommended a mobilization therapy using Succimer (dimercaptosuccinic acid) for 4 patients who have persistently showed elevated blood mercury levels, and further work-up for 3 children. Conduct of additional laboratory tests were made which included an EMG-NCV test for 10 patients, EEG test for 1 patient, urinalysis, fasting blood sugar for 2 patients, TSH/T4 for 1 patient. Other medical management measures included the provision of multivitamin supplementation, esp. Vitamin B complex, monthly check-up of all exposed individuals for at least a year to monitor long-term effects (tremors, behavioral changes, etc), conduct regular monitoring of blood/urine mercury levels and set-up a surveillance system in coordination with the City Health Office. A comprehensive monitoring plan for a period of 1 to 1.5 years was recommended by the NPMCC to include family members of the 6 students who brought mercury into their homes.

Arrangements by the Department of Education with the School Authorities:

The school authority informed that students are currently attending classes at the nearby school since March 22. Dep-Ed has been providing assistance for the issuance of a certification for students who are graduating which was needed for admission to college. Dep-Ed has issued a circular adopting the DOH guidelines on the safe use and handling of Hg and possible banning/phase-out of mercury.

The IACEH recommended the banning/phase-out of mercury in schools. Guidelines for the phase-out plan and disposition of available mercury in schools was needed. Dep-Ed to conduct an inventory/mapping out of mercury in schools (Possibility of including other chemicals in the inventory). Arrangements for special consideration was extended by DepEd to the school

ENVIRONMENTAL ASSESSMENT AND CLEAN-UP:

On March 17, 2006, the DOH prepared letters to the the United States embassy coursed through Department of Foreign Affairs (DFA) for technical assistance from the US-EPA and a letter of request to a multinational company to borrow its mercury direct reading instrument from its offshore operations.

During this period, the congressional representative of the district decided to call a congressional inquiry among government agencies, the local government units, the school authorities and other stakeholders to determine whether activities to facilitate the clean-up were undertaken including the necessary steps to implement said activities at the soonest possible time.

Then on March 25-27, 2006 technical assistance was provided by the multinational petroleum company for the assessment of the mercury levels using the Jerome mercury vapor analysis (MVA) model 431X direct reading instrument. The Jerome 431-X MVA portable hand-held unit uses a patented gold film sensor for accurate detection and measurement of toxic mercury vapor in the air within the range of 3 ug/m3 – 999 ug/m3. Mercury levels are measured within a 10-second cycle. Two Malaysian (2) staff from the company trained a team on the use of the equipment for monitoring purposes. A thorough monitoring was done on the classrooms in the school including the surrounding premises

A briefing was made prior to the actual sampling at the parish office. The stockpile of clothes surrendered by the parents of the students were placed in plastic bags in the office. Measurement of mercury levels using the LUMEX mercury vapor real time monitoring showed levels of 3 - 5 ug/m3. The team requested the school authorities to place these materials in polyethylene plastic bags and store in a separate area. The sampling methodology for his activity included the following;

1. The sampling teams were grouped into two persons per team. A buddy system was adopted. It was agreed that the sampling team would wear level B protection.
2. A floor plan was provided by the school authorities. Keys were segregated per sampling area/floor.
3. Levels were measured along the hallway and prior to entering the classrooms. Doors were opened and another measurement was done.
4. If Hg levels >0.1 mg/m3 take extra precaution.
5. Hydration was recommended because of the very humid and warm temperatures prevailing in the area. .
6. Sampling design for each room was dependent on previous sampling done.
7. Sampling areas were divided into grids to cover all areas as much as possible. Three sampling zones were assessed which includes measurement near the floor, estimated breathing zone of a child while in the classroom and the adult breathing zone. Additional samples were also measured (e.g. airconditioners, trash can, chairs, fixtures, computers etc.). If crevices are present, sampling point was divided into at least 10 areas to determine possible presence of mercury beads. Levels were measured as reflected in the monitor. If mercury beads were visible additional sites for assessment were included. Levels in the hallway, stairwells, comfort rooms, canteens and potential "deadspaces" were also measured. Each room was monitored for 10-30 minutes depending on the potential mercury contamination. Sampling was also done at the comfort room focusing on the possible mercury levels in the sink where elemental mercury might have been disposed down the drain and washings from contaminated hands and materials
8. In case of emergency at any given time during the sampling, immediately "pull-out" from the area.

Sampling Areas:

Six areas were included in the sampling plan which included the administration, new, high school buildings, Church, parish office, canteen extension, guard house and the parking area.

Personal Protective Equipment:

It was agreed upon that level "B" protection would be used to monitor the spill areas based on the highest levels previously recorded at 112 ug/m3 (February 22, 2006). Due to lack of mercury vapor cartridges, level B protection was likewise used in monitoring the "non-spilled" areas.

Decontamination:

The decontamination area was set-up by the SRU in the parking area which had lower levels of mercury detected.

Briefing and Preparations:

After the briefing, the teams proceeded to the school premises. Measurements were done at the parking area and waiting area where the staging and decontamination area were set-up.

Results of the monitoring:

The highest mercury vapor readings were recorded at 525 ug/m3 (floor readings) at Room 131 which was one of the rooms that was initially cleaned-up. Visible beads of mercury were seen at the floor and at the cracks and crevices in the room. *Note: Not detected (ND) readings indicated in this report does not mean that no or zero mercury levels were detected but rather the detection limit of the equipment is at 3 ug/m3. Levels below 3 ug/m3 were reported as ND.*

Efforts by the Local Government Unit:

A Lumex unit was bought by the local government unit. Arrangements were made by the City Health Office to conduct training of the use of the machine for local/government personnel and practicum at the school afterwards.

Private Clean-up Company:

The DOH also received a letter offering to manage the clean-up process from a private multinational company and a private clean-up company (with affiliation with a Netherlands-based company) to undertake clean-up of mercury of the school. A consortium of a multinational company, a Netherlands-based clean-up service provider and a local clean-up contractor had undertaken the clean-up of activities for mercury contamination at the School. The consortium had committed to undertake a holistic, comprehensive, technically sound and acceptable approach to ensure that prescribed clean-up measures have been implemented, at no cost to the government and in accordance with the health guidelines as agreed upon with the IACEH. The Netherlands-based company recommended to adopt the Dutch tolerable concentration in air of 0.6 ug/m3. Clean up and remediation activity was estimated to be completed in 3 to 4 days.

The Netherlands-based company recommended the following approach for the clean-up:

1. Vacuuming of cracks and crevices in the floor; using HEPA equipped active carbon cleaner specific for mercury clean-up
2. Chop away the surfaces of cracks and crevices of at least 1-2 cm. The mercury can adhere to the top layer of cracked concrete and possibly have been introduced

into the pores of the concrete. Mercury in the concrete cannot be removed with the vacuum cleaner. After chopping, vacuuming all cracks, crevices and surrounding area should be repeated thoroughly, to ensure removal of all concrete particles and dust. A grinding machine should not be used, since this causes too much dust which potentially contains mercury, thereby contaminating the rooms and causes risks to workers.

3. Filling up the cracks and crevices with non-shrinkable cement (preferred over sealing).
4. All wastes generated including the waste collected with the vacuum cleaner should be disposed of by a certified contractor in impervious sealed containers.
5. Supervision of the contractor's activities
6. Forced ventilation and additional air monitoring.
7. Health and safety considerations (PPE, etc) were observed while carrying out the work.

A teleconference with the company and the local contractor was also done with the DOH to discuss issues the proposal and that were not included in their proposal (i.e. airconditioning systems, computers, chairs, other classrooms, disposal of wastes, standards, etc)

Initially a buffer zone was established and covered with polyethylene plastic. These plastic-lined buffer zones separate the working area from the clean area. Persons, materials and equipment were only allowed to go to the clean area after proper decontamination and removal/disposal of coveralls, booties and gloves. Tables, chairs and other furniture inside the classrooms were arranged to have a bigger working area. Air-conditioning units were taken down, wrapped in polyethylene sheets and set aside.

Table 3: Mercury monitoring results after second clean-up

Areas Monitored	**Ambient Mercury Concentration (ug/m^3)**	
	Pre-Clean Up Level* (DOH) May 04,2006	***Post-Clean Up** (May 15, 2006)***
Parking Area		bdl
Room 129 Floor Area Breathing Zone	 5.36 0.072	 Bdl
Room 130 Floor Area Breathing Zone	 0.08 bdl	 Bdl
Room 131 Floor Area Breathing Zone	 bdl 0.328	 Bdl
Faculty Room		Bdl
Library		Bdl
Canteen		Bdl
Male CR-First Floor		Bdl
Male CR-Second Floor		Bdl
Room 218		Bdl
Hallway of Rm 131	0.3	

**NIOSH 9003 method – 1 hour sampling*
bdl – below detection limit (The detection limit of the sampling using a low flow sampler and analytical method using the Hiranuka mercury analyzer is **0.005 ug/m ^{3})*

An information desk was established by the IACEH communications team in coordination with the school authorities to respond to queries on the clean-up being undertaken. A communications plan (COMPLAN) shall be formulated by the Occupational Safety and Health Center of the Department of Labor and Employment, the Center for Health Development (CHD) and the Department of Environment and Natural Resources (DENR) at the National Capital Region to provide information to all concerned stakeholders regarding the IACEH initiatives to resolve this problem. An information and assistance help desk shall be established.

During the IACEH meeting, results of the monitoring was discussed. Information provided revealed that during the first clean-up, levels below the detection limits were measured but, visible mercury beads were still present. The IACEH recommendation made was that for as long as mercury beads are present, the clean-up is still rendered incomplete. The first clean-up done did not satisfy the requirements because there were still visible Hg beads present. Part of the ocular survey that needs to be done with the USEPA is the monitoring for Hg “hotspots”. This would be done using the Lumex and a mercury tracker which would identify the “hotspots” where the Hg may still be present. This is to ensure that there will be no more “hotspots” of Hg with levels >10 ug/m3 that would vaporize. There might still be some beads left which may re-contaminate the rooms.

Clean-Up Activities Undertaken by the US-EPA:

Coordination was made with the US-Embassy on the needs for clean-up and antidotes. These included logistics such as plane fare, board and lodging, equipment and supplies. A series of teleconferences between the DOH and the US-EPA was done on March 21 and April 5, 2006. The USEPA inquired as to the activities undertaken and mentioned that in some instances clean-up activities are done several times. Initial measures recommended by US-EPA team included amalgamation/ inertization with the addition of sulfur/ sealing of rooms.

Arrangements on the travel of the USEPA team was arranged by the Office of Representative of the 1st district with the owner of the Philippine Airlines. The company's Foundation issued the round trip tickets for the 4-man EPA team. Accommodations were also provided by the owner of the airline company, transportation and all other incidental expenses were shouldered by the Congressman's Office. Arrival of the team was scheduled on May 18 and May 19 for the Las Vegas and San Francisco EPA staff, respectively.

The terms of reference for the USEPA team included provision of technical advise and guidance in the remediation of the mercury spill at the school and specifically includes the following; (a) interpret data previously gathered by the Philippine Government (b) assist in identifying the extent of contamination within the school grounds (c) identify next steps in the clean up process; and (d) assist in determining parameters for when the school can safely reopen.

The USEPA team from Las Vegas and San Francisco were composed of Steve Calanog, Brian Bass, Dianne Newell and Philip Campagna. The ocular inspection with the EPA will be done in collaboration with the IACEH. The private clean-up company was requested to take part of the clean-up under the supervision of the USEPA. The USEPA team would bring the equipment for on the job training in the use of Hg tracker and Lumex. A laboratory would also be needed to compare the results of the NIOSH 6009 and the OSHC method. The OSHC was identified to be the laboratory

During the inspection made by the US-EPA, mercury beads were still visible on a crack on the floor of Rm 131. The USEPA team used a LUMEX real-time monitoring equipment to inspect the area. Hotspots were detected in Rm 131(>30 ug/m3 on top of a sealed crack on the floor) and along the walkway in front Rms 129-131.Spots were marked with the reading. Windows were closed over the weekend to let the mercury vaporize. Mercury concentration in the air were again measured the following Monday. Air monitoring in Rm 218 showed that Hg level was still >10 ug/m3. The USEPA team sprayed the gutter with MercX® as part of the initial remediation. Other areas were likewise sprayed with MercX.® Spraying the floor with MercX® to amalgamate and prevent re-vaporization whatever remaining mercury in the flooring. Furnitures were wrapped in plastic to trap the mercury vapor being emitted for measurement the following day. These were eventually declared “clean”. The wooden floor of Rm 218 was sawed off and replaced. Sawdust was then collected and vacuumed. Workers used Tyvek® and mask with mercury cartridge. The cement flooring in Rm 131 was coated with epoxy paint to further seal in whatever mercury vapor that might be emitted. The Hg concentration inside the room was re-measured and found to be in levels that will not present a health concern.

On clarification with the school authorities: the classrooms that were remediated will be used as faculty rooms (i.e. Rooms 129,130 and 131) The pupils will be using the classrooms in the new building. For Room 218, a decision would be made after consultation with the management. An existing EPA guideline for the decision-making process in the disposition of contaminated materials were followed. Materials with levels monitored above 10 ug/m3 were recommended for disposal. Airconditioning, furnitures/fixtures, clothes, trash bins, chairs and lockers from the contaminated areas with levels > 10 ug/m3 will be disposed of as hazardous waste.

Based on IACEH resolution no 2006-0007, remediation measures utilizing all the necessary equipment, materials and construction works to remove all possible mercury and mercury contaminated materials were implemented under the technical guidance and supervision of the USEPA. All furnishings and fixtures (including lockers) found to be contaminated, along with porous materials that mercury vapor may have penetrated were removed. All surfaces in the rooms were then washed with HgX® Mercury Decontamination solution to stabilize any remaining mercury contaminant and sealed off with epoxy-based paints;

Ambient Air mercury levels after Clean-up
May 26, 2006

Area of concern	Prior to remediation works (ug/m3)	After the remediation works (ng/m3)
Rm 130	**0.290**	**0.085**
Rm 131	**1.150**	**0.220**
Rm 218	**12.260**	**0.921**
Rm 217	**2.250**	**0.045**

Based on the ambient mercury monitoring the levels monitored in the mercury contaminated rooms including all the other rooms and immediate premises were already below the safe guidelines of 1 ug/m3 clearance criteria for mercury vapors that was set for the re-occupancy after the completion of the remediation works. The USEPA technical team expects that forced ventilation of the rooms will eventually disperse/dissipate the mercury vapors and further lower/reduce these levels. Hg-contaminated furnitures/fixtures have been removed and remedial measures through appropriate methodologies and procedures have been satisfactorily completed. The IACEH members of the Task Force Mercury in a meeting last May 26, 2006 at the DENR hereby concurs with recommendations of the technical experts for the resumption of the operations of the School and opening of classes for the school year CY 2006-2007, effective immediately. Three (3) children were hospitalized at PGH. Home visit conducted in one of the students who brought home mercury samples as souvenirs. Results of the air sampling showed mercury levels at the door step, rag at the entrance, living room, bedroom of the student, kitchen and cabinets. All were within the recommended ATSDR guidelines of 10 ug/m^3. The trash can where the mercury beads were disposed off, showed Hg levels of 7 ug/m^3. Although this was within the guidelines, the team recommended for the eventual disposal of the trash can. The practice of the household members of leaving their shoes outside of the front door minimized further dispersion of the mercury into the home.

The local government unit (LGU), the congressional representative and the school authorities had provided its full support to the different government agencies to immediately address and resolve these problems. Monitoring of residential homes were conducted by the LGU.

Lessons Learned:

1. There is a need to conduct information and education campaigns to raise the level of awareness of the various stakeholders on the acute and chronic toxicity and health effects of mercury especially among schools.
2. Prompt, appropriate and immediate clean-up of the mercury spill would have reduced/mitigated the impact of the incident. Preventive public health intervention measures should be implemented as soon as possible. Risk communication is an important aspect of the chemical emergency response system
3. There is a need to review/improve/strengthen the government's capability to immediately and actively respond to chemical emergencies including rapid assessments. First response programs on chemical incidents in the various settings i.e. homes, school, hospitals, industry, etc should also be established.
4. Decontamination procedures should be immediately implemented for chemical exposures, as necessary.
5. All mercury contaminated clothings, shoes, school supplies, etc, should be immediately decontaminated, surrendered for proper disposition.
6. There is a need to review the school curricula involving hazardous chemicals.
7. Standards and regulations to be adopted are dependent on the situation, susceptible population and prevailing conditions in the environment.
8. Sampling methodologies should consider the inherent characteristics of the most vulnerable population (e.g. breathing zones of children compared with adults, proximity of the children's breathing zone to the ground, etc.)

IACEH resolutions, health, environmental clean-up measures and policy recommendations have been promulgated for implementation by the different concerned agencies and stakeholders to harmonize and streamline all efforts/actions to implement immediate, coordinated. timely and appropriate strategic public health and technically acceptable environmental interventions to protect the health of the people and the environment.

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** This report was synthesized from the IACEH reports, resolutions and communications during the course of the incident. This case report was also provided to UNEP to provide learnings and insights especially among developing countries who may not have similar constraints and limitations in responding to chemical emergencies. This report is not intended to be an audit or oversight of the government agencies actions but rather only a narrative of the incident as it happened based on the viewpoint of the Secretariat of the subsector of the IACEH. Inclusion of products in the report does not constitute explicit indorsement of their products by the DOH.*

Facts and Challenges of Mercury Pollution in Goldmining in Indonesia

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Abstract

Findings from studies of mercury use in goldmining in several places in Indonesia suggested that an impending health problem of mercury poisoning was on the way. The escalating use of mercury in goldmining throughout the country was recorded rampant during recent years triggered by the economic crisis in the country beginning in 1997. Surveys done on people, rivers, and fishes revealed the increasing mercury content, reaching levels that might endanger present and future generations. A survey done in 2003 revealed that 180 tonnes mercury released into the river Kahayan in Kalimantan annually. While the health arena is still struggling with infectious diseases and nutrition problems, this new problem is imminent. Socio-economic factors were among other factors involved in the practice of small-scale goldmining.

Key words: mercury, pollution, goldmining

Introduction

Although mercury is released from natural sources and man activities such as the eruption of volcanoes, incineration of waste, or the burning of coal; mercury use in small scale gold mining in Indonesia had significantly increased the potential health threatening exposure to the populations. Small scale gold-mining work was widely spread throughout scattered sites in the islands of Sumatera, Jawa, Kalimantan, Sulawesi, Papua, Maluku, and Sumbawa (Fig. 1).

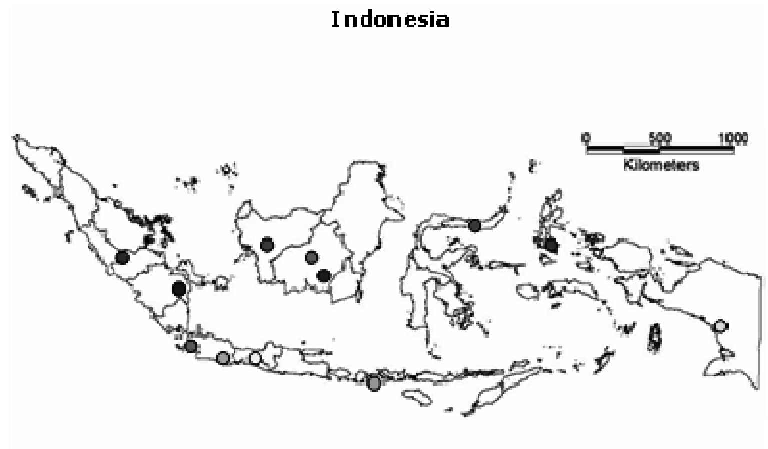

Fig. 1 Some gold-mining fields

The sites were previously covered by dense tropical rainforests that support the balance of global climate. By the activity of gold-mining, the thick woodland was transformed into deserts of acid rock land which cannot be cultivated like before.

Mercury Use in Small Scale Gold-mining

With the excavating of the earth in gold-mining work, damages started in the previously isolated areas. Still pools of water like tens of meters depth pits or parts of stagnant dirty water of rivers and creeks were building up in the sites. These bodies of water would eventually serve as newly added breeding grounds for malaria-carrying mosquitoes. The impact was clear; malaria transmission was accentuated in the area. Other damage done by the activity was the impact of the use of mercury.

While the use of mercury in gold-mining had been done by the local people ever since history recorded, it was cited that the escalating use of mercury in Indonesia was triggered by the economic crisis in the country beginning in 1997. From that time on, the environmental impact due to mining activities was substantial, even more serious when the use of mercury was practiced by the ever growing small scale gold-mining activities. Reports on mercury contaminations were presented in media as well as in meetings.

Besides the physical alteration of the area, the introduction of mercury into the environment was frightening. A report in 2002[1] stated that 340,000 miners were operating in the islands of Kalimantan, Sumatera, Jawa, Sulawesi, and Papua. At least 44,000 sites of small scale gold-mining were detected covering an area of 37,000 kilometer square.

It was also estimated that in the year 2002 no less than 114 tons of mercury was polluting the environment annually. This finding was intensified in 2003 by a report that nearly 180 tons of mercury was released into the environment in the provinces of West and Central Jawa, Sumatera, Central and East Kalimantan, North Sulawesi and other sites annually[2].

During the processing of ore with mercury some amount of mercury was lost. A total of 14.5 percent of mercury was released into the environment every time it was used to extract gold from the ore. Of the amount of mercury released into the environment 10 percent was released from the amalgamation process, 2.5 percent from the burning of amalgam, and 2 percent from the concentrate in tailing.

It had been detected that for the production of 30 tons gold per year by the small scale gold-mining, 38 tons of mercury vapor was released into the air from amalgam burning, 28 tons of metallic mercury in tailing that ultimately would be in the water bodies and sediments, and 76 tons of metallic mercury from amalgam processing was directly disposed into the water bodies and sediments. These figures may be used as a reference to chose methods of controlling the mercury contamination. Insofar, no effective effort was observed that prevent mercury from contaminating the environmental compartments.

Impact done by the direct disposals of mercury into the environment had been reflected in the concentrations of mercury found in the environmental compartments (Table 1). A report in 1996 detected that the Kapuas River in West Kalimantan contained an average concentration of 1.02 ppb total mercury in the water and 0.19 ppm in the sediment[3]. In West Jawa, a study reported that the Cikaniki River[4] contained 0.14 mg/L to 0.55 mg/L mercury in the water and 3.58 mg/kg to 28.38 mg/kg mercury in the sediment. Another report described that the Pongkor River[5] contained a maximum of 2.5 ppb mercury while in the sediment they found mercury ranging from undetected to 2688 ppm in the sediment. They also found mercury in soil ranging from 1 ppm to 1300 ppm in soil and from 615 ppm to 1058 ppm in tailing. In the sediment of the Totok River estuary (Sulawesi) mercury concentrations ranged from 9.96 ppm to 78.9 ppm. The Kahayan River in Central Kalimantan[6] showed mercury concentration of 0.053 mg/L in the water and 6.22 mg/L in the sediment. Although within the acceptable concentration, rivers in Hargorejo and Kalirejo in Central Jawa[7] showed mercury concentration of 0.0022 mg/L and 0.0017 mg/L in the water consecutively. In Tasikmalaya[8] a survey reported mercury concentration ranging from 0.121 ppm to 642.105 ppm in the sediment.

Table 1. Mercury Concentrations in Water, Sediment, and Soil in Gold-mining Areas of Indonesia

Rivers in Gold-mining area	Mercury concentrations in:	
	Water	Sediment
Down-stream Kapuas River (West Kalimantan), 1996[3]	0.8 ~ 1.2 ppb (aver.: 1.02 ppb)	0.13 ~ 0.33 ppm (aver.: 0.19 ppm)
Cikaniki River (Pongkor),1999[4]	0.14 ~ 0.55 mg/L	3.58 ~ 28.38 mg/kg
Pongkor River, 2000[5]	Maximum 2.5 ppb	0~2688 ppm (5 out of 231 locations: >1000 ppm; In soil: 1~1300 ppm; in tailing: 615 ~ 1058 ppm)
Totok River (Sulawesi), 2000 [6]		Estuary: 9.96 ~ 78.9 ppm
Kahayan River (Central Kalimantan)2001[7]	0.053 ± 0.009 mg/L	6.22 ± 1.16 mg/L
Hargorejo (DIY)2004[8]	0.0022 mg/L	
Kalirejo (DIY)2004[8]	0.0017 mg/L (limit: 0.002 mg/L)	
Tasikmalaya 2005[9]		0.121 ~ 642.105 ppm (limit: 0.01 ppm, Govt. Reg. no.18/1999)

Note: Parts of this table had been presented in: Inter-Regional Workshop “Environmental Health Impacts from Exposure to Metals”, 1~3 June 2005, WHO, India.

Mercury in Fish

These high concentrations of mercury in major environmental compartments, namely water and sediment, was soon had its subsequent impact in the higher levels of the food chain. Mercury was found in fishes from the area of gold-mining.

Referring to the Japanese Provisional Standards of 0.4 ppm for total mercury in fish[10], some study revealed mercury concentration in fishes that exceeded the limit. In North Sulawesi surveys reported the increase of mercury concentration in fishes from year 2000 to year 2004. A report in year 2000 stated a total mercury concentration of 0.58 ppm[11] in fish which by the year 2001 the figure increased to 2.08 ± 0.38 ppm[12] and to a range of 8.4 ppm to 23.4 ppm[13] in the year 2004. These were quite substantial increases of mercury concentration in food.

Handling of Mercury and Its Potential Health Impact

The miners bought mercury for approximately $ 60/kg in the local market. They handled mercury carelessly. Mercury was stored in the house openly in rooms where the whole family lived with potential exposure to themselves. During the extraction process of gold the miners directly manipulate mercury with their bare hands. No particular measures were taken to prevent any direct exposure to the metallic mercury during this process of amalgam building.

The process usually involved the use of abundant water and was done in the river or places close to the water body. In this process some excessive metallic mercury was lost into water ways and rivers. Later, at the process of burning the amalgam, the strong smell of the mercury fume drove the miners to avoid a direct exposure but left the fume to fly freely to the air by means of stacks. In due course the fume would be washed by rain and found its way to the water bodies. In water, the mercury was accessible to the fishes or directly exposed to the community that consumed the water.

A further transformation of inorganic mercury to organic mercury especially methyl mercury compound in the water body and the sediment would raise a problem of the contamination of fishes with methyl mercury and eventually the contamination of the community who consumed the fishes.

In the community, some clinical signs leading to mercury contamination among the miners had been reported by recent investigation in Tatelu area (North Sulawesi)[14]. Some subjective symptoms were claimed by the miners including the decline of their general health, metallic taste, and salivation problems. Medical examination also detected symptoms of Intentional tremor, mainly fine tremor of eye lids, lips and fingers, ataxia, and dysdiadochokinesia.

Conclusion

To survive economically in times of economic crisis, small scale gold mining work was done by some segment of the community. For some of the miners the work was done as a part-time job between harvests.

The use of mercury in gold-mining in several places in Indonesia suggested that an impending health problem of mercury poisoning was on the way in some populations. Different types of health problem could be recognized. The miners and their family that lived in the mining sites were potentially suffered from metallic mercury contamination. Fume of mercury was spread into the air and contaminate other population around the vicinity. Also, mercury fume that lost into the air would eventually be deposited into water body and transformed into methyl mercury that would be introduced to the local diets.

With the destruction of a wide area of natural forest and the surrounding mining area the small scale gold-mining activities gave rise to a new breeding place of malaria-carrying mosquitoes and enhanced the malaria transmission already existed in the community. Floods and alteration of habitat for the fauna and flora due to silt dumping were also disastrous and finally, acid mine drainage would destroy a wider area of the land.

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