ICMGP 2024 workshop
NIMD forum 2024

Strengthening Research Capacity on Mercury in Low and Middle-Income Countries with a Focus on Vulnerable Populations

21 July 2024
Cape Town International Convention Centre
Cape Town, South Africa

Program

9:00 – 9:05 Brief Introduction of NIMD Forum 2024

Koichi Haraguchi *NIMD, Japan*

Opening Remark

Masatake Fujimura *NIMD, Japan*

Chairs: Koichi Haraguchi *NIMD, Japan*

9:05 – 9:20 Examination of Hair Mercury in Areas at Risk of Mercury Pollution Around the World

Masatake Fujimura *NIMD, Japan*

9:20 – 9:35 Open Laboratory Concept in Asian Institute of Technology for Mercury Analysis and Training

Chacriya Malasuk *Asian Institute of Technology, Thailand*

9:35 – 9:50 Mercury Analysis Made Easy

Alvin Chua *Nippon Instruments Corporation, Singapore*

9:50 – 10:05 Development of simple analytical method for mercury in biological samples and technology transfer

Megumi Yamamoto *NIMD, Japan*

10:05 – 10:10 Ensuring Consistency in Mercury Analysis: Collaborative Efforts Under the Minamata Convention

Koichi Haraguchi *NIMD, Japan*

Chairs: Mitsugu Saito *UNEP, Thailand*

10:10 – 10:25 Coffee Break

10:25 – 10:40 Preliminary findings of the mercury exposure assessment in Maldives

Nafha Abbas *Ministry of Climate Change, Environment and Energy, Maldives*

10:40 – 10:55 Balancing Tradition and Health: Addressing Mercury Exposure in Nepal's Gold-Plating Workshops

Bhupendra Devkota *College of Applied Sciences-Nepal, Nepal*

Chairs: Megumi Yamamoto *NIMD, Japan*

10:55 – 11:10 Mercury Exposure in the Tapajós River Basin: Investigating Gold Mining Impacts on Aquatic Ecosystems and Community Health

Ricardo Bezerra de Oliveira *Federal University of Pará Western, Brazil*

11:10 – 11:25 Rising Mercury Pollution in Nigeria and Compelling Need for Surveillance: A Scientific Priority

John I. ANETOR *College of Medicine, University of Ibadan, Nigeria*

Chairs: Masatake Fujimura *NIMD, Japan*

11:25 – 11:40 Mercury (Hg) exposure and associated health risk among electronic waste (e-Waste) recyclers in Bangladesh.

Sarker Masud Parvez *Environmental Health and WASH icddr,b, Bangladesh*

11:40 – 11:55 Mercury flow analysis to identify and monitor national mercury situation

Mitsugu Saito *UNEP, Thailand*

11:55 – 12:00 Closing Remark

Mitsugu Saito *UNEP, Thailand*

Examination of Hair Mercury in Areas at Risk of Mercury Pollution Around the World

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The most effective method to understand the human health effects of harmful substances such as methylmercury (MeHg) at the early stage is assessment of the exposure level. “How much of the harmful substance is taken into the body”

It is known that MeHg uptake from foods into the body is excreted by urine and feces and accumulates in hair at a constant rate. The concentration of mercury in hair is an effective indicator to understand the level of human exposure to MeHg. The purpose of this investigation is to assess the MeHg exposure level around the world by measuring the hair mercury level of the inhabitants in regions where MeHg pollution is possible by gold mining, factory pollution related and fish-eating habits, and to contribute to prevention of related health hazard.

Health hazards caused by MeHg are more likely to occur in developing countries than in developed countries, but it is difficult to determine the mercury contamination status in developing countries because they often lack sufficient mercury measuring equipment and technology. We advertised hair mercury analysis for developing countries using our Institute’s homepage. After contacting with on-site collaborators over the E-mail, they sent us approximately 6,500 hair samples during 2003 to 2024. Among these sampling areas, hair samples from upper Maroni area in French Guiana included high concentration of mercury. The average concentration of total mercury was remarkable high at 9.4 ppm for male (153 samples) and 9.9 ppm for female (234 samples), respectively. In 52 highly mercury contaminated samples (> 10 ppm), we found that 94.5% of mercury was in MeHg. The hairs were collected from residents who were in the habit of eating fish near gold mines, suggesting that the high hair mercury concentrations were due to the consumption of mercury-contaminated fish.

We found some mercury pollution areas, especially in upper Maroni river of French Guiana. These results show that our research attempts using our homepage are very useful to discover mercury pollution around the world.

Open laboratory concept in Asian Institute of Technology for mercury analysis and training

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A mercury laboratory was opened at IDEA EEM Laboratory/IDEA R&D Center of the Asian Institute of Technology (AIT) supported by IDEA Consultants, Inc and Nippon Instruments Cooperation (NIC). The laboratory has been established in 2017 for dealing with environmental engineering and infrastructure issues. Since then, new instruments have been added to expand its capacity for mercury analysis. Three instruments dedicated for mercury analysis are currently in operation. They are Direct Mercury Analyzer with direct thermal desorption technology, Gaseous Mercury Analyzer for measuring wide range of gaseous matrices, and Gas Chromatograph with Electron Capture Detector which can speciate organic mercury content.

The laboratory aims to bridges the gap between academia and practitioners. The cooperation facilitates researchers from AIT and other organizations to undertake different types of activities. It offers analysing various type of environmental and biological samples for external researchers who do not have mercury analytical capacity. In addition, the laboratory can organize and implement hands on trainings to researchers/technicians to learn the protocols of laboratory analysis for mercury. It is also open to researchers who bring their own samples to analyse mercury by themselves. The laboratory provides an innovative model to enhance mercury research particularly in developing countries.

The laboratory has responded the requests from UNEP for analysing human hair samples from Palau and Maldives to assess the level of human exposures in general public. Also, a hands-on training will be organized later this year. Many other activities will be provided for those who wish to utilise this facility.

Mercury Analysis Made Easy

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In analytical measurement, it is always important to be able to quantify to obtain an accurate result. Among most elemental analysis, mercury measurement has always been an analytical challenge due to its unique properties and detection levels. Such challenge reflects more significantly to both least developed and developing countries which may not have access to both the resources and knowledge capacities to produce reliable measurement results, eventually affect to the relative accuracy of the scientific data contributed which can compromise to the outcome on the effectiveness evaluation of the Minamata Convention Treat on Mercury.

As a technology solutions company, Nippon Instruments Corporation (NIC) - Japan, with our more than 4 decades of mercury analysis knowledge and engineering innovations, continues to develop instruments with practical yet affordable solutions, to allow users of all levels to able to possess and operate to produce quality mercury results to meet their requirements. In fact, accuracy of mercury analysis results starts from sampling, if improperly managed, can directly affect to the results. In this workshop, NIC would like to introduce our range of compact field-portable Mercury analyzers, with simple yet reliable and established thermal decomposition - AAS technology, which can allow direct field measurements of samples of different types of matrices like soils, plants, animal tissues, human hair, blood, urine, wastewater, ambient air and more. Different kinds of possible applications, measurements and usages will be elaborated for discussion.

Development of simple analytical method for mercury in biological samples and technology transfer

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Since methylmercury (MeHg) can affect the central nervous system, it is important to determine the concentration of MeHg in the target samples for risk assessment. Since MeHg and inorganic mercury have different modes of transport and toxicokinetics in the body, analysis of MeHg in addition to total mercury (T-Hg) is necessary depending on the situation. In some cases, analysis of MeHg in fish will be required from the perspective of exposure assessment, since humans are exposed to MeHg mainly through the consumption of seafood. In developing countries where environmental pollution due to mercury is a problem, it will be difficult to perform routine mercury analysis that requires expensive equipment, high running costs, and advanced technology.

Based on this background, the mercury analytical method developed by the authors can measure T-Hg and MeHg in the same biological sample through a series of operations. After heating and dissolving biological samples (e.g., fish) in NaOH, followed by a degreasing step using MIBK and hexane, T-Hg is measured by analyzing the solubilized sample solution after removal of these organic solvents with a mercury analyzer based on direct thermal decomposition-gold amalgamation-cold vapor atomic absorption spectroscopy. The solubilized solution is then treated with HBr, $CuCl_2$, and toluene, and the organic mercury fraction in the toluene layer is finally inverted into cysteine solution, and analyzed with the same analyzer used for T-Hg measurement. This method has been applied to mercury analysis in tissues of fish and experimental animals, and recently to mercury analysis in the development of CRM for whole blood.

In addition, our laboratory accepted researchers from countries with environmental problems related to mercury contamination to participate in short-term training programs on mercury analysis. In this presentation, we will also introduce these trainings and collaboration with overseas countries.

Ensuring Consistency in Mercury Analysis: Collaborative Efforts Under the Minamata Convention

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Robust and reliable data collection is crucial for evaluating the effectiveness of the Minamata Convention on Mercury. Comprehensive and standardized monitoring allows for establishing baseline levels, tracking changes over time, and identifying high-risk areas that require intervention. Proficiency testing and the development of Certified Reference Materials (CRMs) for mercury analysis play a critical role in ensuring the accuracy and quality of this data. This presentation discusses collaborative efforts to develop CRMs for mercury analysis in hair, blood, and urine to enhance the precision and reliability of mercury exposure biomonitoring. It also evaluates the performance of laboratories in the Asian region, emphasizing the importance of proficiency testing in maintaining high analytical standards. While accuracy is crucial for mercury exposure assessments, the proficiency level required for these measurements can be lower due to incorporating safety factors in guideline values, which provide a buffer for individual variability and uncertainties. Conversely, detecting subtle changes in mercury concentrations over time and across regions requires a much higher proficiency level to ensure data reliability and robustness. Our analysis underscores the need for differentiated proficiency level requirements based on the specific aspect of mercury monitoring. This presentation will compare the skills of reference laboratories participating in CRM studies, the proficiency of laboratories in the Asian region, and the proficiency levels required for different analytical methods. Through these collaborative efforts, we aim to ensure that mercury monitoring remains a powerful tool for protecting public health and the environment, fostering a safer future for all.

Preliminary findings of the mercury exposure assessment in Maldives

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Maldives is in the process of becoming a party to the Minamata convention on mercury and had published the Minamata Initial Assessment (MIA) in 2019, in partial fulfilment of the ratification process. The MIA revealed significant environmental impacts (land, water, air) from waste incineration and open waste burning practices, as well as use and disposal of mercury containing products such as electric switches, relays, and batteries. Furthermore, trace amounts of mercury were found in fish products made in the country, indicating a potential risk of exposure for the Maldivian population.

Fish consumption is considered the primary pathway of methylmercury exposure worldwide. This is especially concerning for a Small Island Developing State like Maldives where (marine) fish consumption contributes to around 71% of the animal-source protein intake of the population's diet – the highest in the world. Despite these high-risk factors, no previous studies had assessed the extent of mercury exposure in the Maldivian population.

This study aims to fill this gap by conducting the first preliminary assessment of mercury exposure levels in the Maldivian population attributed to high-level fish consumption in the daily diet. The study hypothesized that given the high fish consumption in the country, Mercury exposure level in the Maldivian population through diet is likely significant. Hair samples were collected nationwide (100 samples – as a preliminary study) from seven regions of Maldives and analyzed for their mercury levels. The presentation will outline this study's framework and results.

Balancing Tradition and Health: Addressing Mercury Exposure in Nepal's Gold-Plating Workshops

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Gold plating on statues, temple roofs and pinnacles including others, has been a traditional practice and profession of Newars, an ethnic community in the Kathmandu Valley, since many centuries. Gold plating uses an amalgam of gold to mercury in different ratios (ranging between1:6 to 1:25 with an average practice of 1:15). Mercury was used in high quantity (12128.25 kg in 2016, 10272 kg in 2021 and 4061.14 kg in 2023) over the years. Department of Archaeology registered a significant decrease in gold-plating (102591 statues) in 2021 due to Corona. Amalgam is applied on the surface of the statue, whole or partial, with an average of 39.586 g Hg/statue. Mercury is removed through fire gilding, leaving a thin coat of gold on the surface. The process is repeated until the desired glow is achieved. As this is done in an open condition, the workforce and others in the immediate vicinity, are directly exposed to high levels of mercury released into the environment. Mercury free technologies such as electro-plating, gold leafing and micro-electroplating are also in practice but both quality and durability of such gold plating are not comparable to that of the traditional amalgam based gold plating. Entrepreneurs are in search of a solution, so that the quality could be assured as demanded by the international and national markets. Severe health effects are observed among the workers and further study on health status of exposed population is also of high concern. Attempts to limit the exposure by introducing better working condition and installation of mercury capture system (MCS) are underway, but the efficiency of the installed MCS is not at desired level. Also, long-term sound management of mercury waste (an average of 84.2 kg/year per workshop) is a priority concern. Efforts to limit mercury exposure in workplace through implementation of Code of Practice and introduction of alternative technologies are underway, so that the traditional and religious practices could be retained, and in the meantime human health and environmental issues could be addressed.

Mercury Exposure in the Tapajós River Basin: Investigating Gold Mining Impacts on Aquatic Ecosystems and Community Health

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Artisanal and Small-Scale Gold Mining (ASGM) activities, both legal and illegal, have become a pervasive issue in the Amazon, leading to uncontrolled mercury (Hg) release into the environment. This contamination poses a significant threat to aquatic ecosystems and the health of communities that rely on fish as a primary protein source. The Tapajós River, a major tributary of the Amazon River, has been subjected to ASGM activities since the 1960s. According to WWF-Brasil estimates, over four thousand illegal ASGM sites operate within the Amazon region. Extensive research has documented the presence of methylmercury (MeHg) in regional fauna, flora, and human populations. However, studies investigating MeHg levels in postpartum women remain limited. This study aimed to investigate the presence of MeHg in the hair of postpartum women residing in Santarém, Amazon region, Brazil, and assess the potential health risks associated with MeHg exposure. Hair samples were collected from 130 postpartum women residing in Santarém in 2024. Santarém, with a population of 331,942, is situated on the banks of the Tapajós River, approximately 369 km from ASGM sites. MeHg levels were determined in hair samples using a Direct Mercury Analyzer (DMA – 80), Additionally, MeHg concentrations were analyzed in muscle tissue from commonly consumed fish species, *Arapaima gigas* (n=62) and *Cichla* spp (n=40), collected from the Tapajós River. The results showed that 90% of postpartum women had MeHg hair levels exceeding the lowest observable adverse effect hair concentration (LOAEHC) of 0.3 mg/kg, which is associated with adverse neurodevelopmental effects in offspring. Mean MeHg concentrations in *Arapaima gigas* and *Cichla* spp were 0.2 and 0.4 mg/kg, respectively. These levels pose a significant health concern, as the World Health Organization (WHO) recommends a maximum weekly MeHg intake of 1.6 μg for pregnant women and young children. Considering these guidelines, only a few grams of these fish can be safely consumed per week. However, fish consumption patterns in some Amazonian families involve daily intake, placing this population at potential risk of MeHg-related health consequences. Eliminating Hg release into the environment is an extremely challenging task.

Therefore, urgent implementation of educational programs for pregnant women is crucial. These programs should provide information on safe fish consumption levels and appropriate quantities.

Rising Mercury Pollution in Nigeria and the Compelling Need for Surveillance: A Scientific Priority

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Manny developing countries, including Nigeria have set a priority of raising their economic base, mostly based on exploration of natural resources. This mainly involves mining for precious metals, especially small-scale artisanal gold mining (ASGM). Small scale artisanal gold mining employs mercury (Hg) for refining the crude ore, and the miners have no training, neither do they use personal protective equipment (PPE) culminating in attendant mercury pollution and poisoning. The highest exposure to vaporized elemental Hg occurs during burning for separating gold from the gold-Hg- amalgam. Artisanal gold mining and associated mercury pollution is of growing concern in Nigeria, but poorly investigated. About 33% of the states are involved, leading to widespread environmental Hg pollution. Owing to the characteristic low volatility of Hg, it spreads to non-mining states, raising the magnitude of the problem. This coupled with a major gold mining neighboring country, Ghana where high environmental Hg levels have been reported and non-boundary restriction appears to raise the magnitude of the problem in Nigeria. Though our previous concern has been largely on lead (Pb) poisoning, recent reports indicate that Hg pollution may be more serious involving vulnerable populations, predominantly women and children who also suffer from malnutrition which raises their susceptibility to Hg toxicity. An interesting observation in one of our previous reports on metal toxicity in cement dust revealed that total Hg (t-Hg) concentration among others from Nigeria was higher than that of the comparator country, USA. The levels of Hg in this study were quite remarkable, which is probably a reflection of the level of environmental Hg pollution in Nigeria. Mercury exerts toxic effects on key organs and systems; the kidney, nervous system, immune system and elicits oxidative stress, mostly from glutathione (GSH) deficit; making Hg pollution a priority scientific and public health issue in Nigeria. It requires collaborative investigation with international agencies such as the National Institute for Minamata Disease (NIMD) in Japan to avoid severe irreversible consequences of mercury intoxication that may be comparable to the classic Minamata disease first reported in Japan.

Mercury (Hg) exposure and associated health risk among electronic waste (e-Waste) recyclers in Bangladesh

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Electronic waste (e-waste) contains numerous chemicals harmful to human and ecological health. In 2019, the Agency for Toxic Substances and Disease Registry (ATSDR) listed mercury (Hg) as one of the top ten most hazardous chemical substances to human health. We conducted an observational study consisting of exposed and non-exposed e-waste recycling sites in Bangladesh. We collected soil and dust samples and analysed using inductively coupled plasma mass spectrometer (ICP-MS) method. We also collected biological samples from 199 exposed and 104 non-exposed e-waste recycling workers to measure metal concentration and biochemical parameters, including haematological, hormonal, liver, cardiovascular, renal and immune markers. Total Hg concentration was measured using the oxygen combustion-gold amalgamation method in the Minamata lab, Japan, while all other parameters were measured at icddr,b, Bangladesh. The mean concentrations of Hg were significantly higher in soil (25.57 ppm) and dust (59 ppm) than non-exposed soil (0.07 ppm) and dust (3.56 ppm; all p: ≤0.001). The maximum soil Hg posed non-carcinogenic ingestion risk (HQ 5.25) for children only (Hazard index: 5.44); the median concentration did not pose risk to child and adult (HI<1). The potential risks of Hg exposure from dust ingestion were relatively higher for children, with a median HQ of 1.24 and a calculated HI of 1.28 (HI>1). Moreover, we identified a significant non-carcinogenic risk from maximum dust Hg for both children and adult (HI: 24.78 and 3.84 respectively). Exposed workers had lower total Hg (THg) in hair (0.38 vs 0.57 ppm) compared to non-exposed individuals. However, we found a positive association between fish intake and elevated THg levels (p≤0.05). We observed changes in haematological concentrations, disruptions in lipids, thyroid function, renal function, and aberrations in blood pressure in e-waste recycling workers than non-exposed workers. However, no biochemical parameters were associated with THg (p≥0.05). Also, oxidative DNA damage did not mediate exposure-outcome relationships (p≥0.05). In summary, the lower hair levels of THg in the e-waste recycling workers were somewhat unexpected, given the higher concentrations of Hg in soil and dust from exposed worksites. It is likely that the individuals involved in our study were not exposed to Hg through occupational exposure, which can result in significant hair THg deposition. We considered THg in hair, which serves as a reliable indicator of methylmercury (MeHg) exposure.

Evidence indicates that MeHg exposure can be assessed through THg in hair, as over 90% of Hg in hair exists in the form of MeHg, primarily acquired through dietary sources, particularly fish consumption. Future studies should consider measuring Hg from other biological media for a more comprehensive assessment. It is important to note that Hg often coexists with other toxic elements, so we cannot eliminate the cumulative effects of exposure that might adversely affect directly exposed workers. Continuous monitoring, longitudinal studies to evaluate the dose-response relationship and effective control measure including occupational health and safety measures such as the use of personal protective equipment while recycling, implementing awareness program are required to protect workers from potential health risks associated with e-waste derived Hg exposure.

Mercury flow analysis to identify and monitor national mercury situation

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For the effective implementation of the Minamata Convention, it is crucial to identify the priority areas from available data concerning the status of trade, use, emission/release and disposal of mercury at the national level and to interpret them into domestic policy. The training package introduces a comprehensive mass flow concept to outline the national mercury situation throughout its life cycle. It supports the improvement of national mercury inventories by compiling various types of information. Mercury flow analysis is an extended scope of the mercury inventories, or the inventories are a subset of mercury flow analysis, whichever comes first.

The training package is composed of multimedia files, i.e., videos, which provide substantive information when organizing a training programme. The video material is prepared using Microsoft PowerPoint with pre-recorded narration embedded in each slide, then grouped by deck in each topic/subject. All contents were compiled in the form of 'Users' manual', which includes not only the presentation videos but also sample training course, pre- and post-training self-test and evaluations, and the supplementary information. This training package enables users to customize their own training programmes by selecting, adding, or modifying the contents. It can easily integrate any additional cross-cutting issues such as gender and human rights available in the reference literature section.

A trainers' training was held in 2022 to familiarise the material developed. A role-playing group work was organized by utilising the materials. Each participant receives a role card and material (data sheets) for understanding the role and then the group discussed the topic from various angles. Through this exercise, the participants can deepen their understanding on what data is available and what are missing, and then develop a workplan to collect information to complete the national mass flow analysis.