MERCURY MONITORING IN WOMEN OF CHILD-BEARING AGE IN THE ASIA & THE PACIFIC REGION

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Mercury monitoring in women of child-bearing age in Asia and the Pacific Region was jointly conducted by UN Environment, Biodiversity Research Institute (BRI), and global NGO network IPEN.

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IPEN is a network of non-governmental organizations working in more than 100 countries to reduce and eliminate the harm to human health and the environment from toxic chemicals.
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UNEP The United Nations Environment Programme (UN Environment) is the leading global environmental authority that sets the global environmental agenda, promotes the coherent implementation of the environmental dimension of sustainable development within the United Nations system and serves as an authoritative advocate for the global environment. The interim secretariat of the Minamata Convention on Mercury, hosted within UN Environment assists countries in working towards the objective of the Minamata Convention, to protect the human health and the environemtn from anthropogenic emissions and releases of mercury and mercury compounds.
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EXECUTIVE SUMMARY

The following report describes a pilot study undertaken by IPEN in collaboration with the Biodiversity Research Institute (BRI) and UN Environment to assess mercury concentration in hair of selected participants in the Asia and the Pacific region.

The pilot study entitled Mercury Monitoring in Women of Child-Bearing Age in the Asia and the Pacific Region was undertaken between 2015 and 2016 by public interest participating organisations (POs) of IPEN under the supervision of the IPEN Project Team. The purpose of the project was to obtain data on the mercury concentration in hair of women of child-bearing age in selected countries of the Asia and the Pacific region. The information will provide a snap shot of mercury levels in small selected populations which may contribute to national information on mercury concerns.

The methodology for the study required IPEN participating organizations (POs) to identify 30-35 women of child-bearing age (denoted as 18 – 44 years old) in a 1-2 locations in each country. The women provided signed consent to participate in the study. Participants were then required to provide a small sample of hair and to complete a questionnaire. The samples of hair were shipped to the laboratories of BRI in the United States for analysis. Women in this age group were selected as they constitute part of the vulnerable sub-population groups at risk from mercury, a potent neurotoxin which can affect both the health of the mother and impact on a range of developmental endpoints in the developing foetus with lifelong consequences.[1]

Women from 6 countries participated in the study providing a total of 234 samples for analysis at the BRI laboratories. The countries included Cook Islands, Kiribati, Marshall Islands, Nepal, Tajikistan, and Tuvalu. The results of the sampling varied greatly between locations but some consistent trends were observed. Women from Small Island Developing States (SIDS) in the Pacific were found to have very high levels of mercury body burden compared to most other locations. This is consistent with data from the study questionnaires and prior studies indicating that most of these women have a diet rich in seafood. Large predatory fish that feature

1 Bose-O'Reilly, S., et al (2010) Mercury exposure and children's health. Curr Probl Pediatr Adolesc Health Care, 2010 Sep; 40(8):186-215.
Grandjean, P., et al (2010) Adverse Effects of Methylmercury: Environmental Health Research Implications. Environmental Health Perspectives, Vol 118. No.8. August 2010, 1137-1145

in the diet of women in the Pacific SIDS are commonly cited in the literature[2] as having high methylmercury (MeHg) concentrations in their flesh. Consumption of these fish results in the transfer of mercury to humans and subsequent elevated mercury body burden as has been suggested in this study.

Of the 234 women who participated in this study 163 (69.2%) had mercury body burdens which exceeded the reference level of 1 ppm total mercury in hair. The basis for the use of this reference level in this study is that it corresponds closely with the U.S. EPA's reference dose (RfD) of

0.1 ug/kg bw/day and a blood mercury concentration of 4-5 μg/L[3] Current scientific literature suggests that adverse effects on the sampled individual begin to occur at[4] or above the reference level of 1 ppm [5]. Recent studies conclude that negative developmental effects may occur at even lower levels[6]

Of the 150 participants located in Pacific Island States, 144 (96%) exceeded the1 ppm reference level. Among participants who lived in areas other than the Pacific Island States 21.4% exceeded the 1ppmreference level. The majority of participants located in countries other than Pacific Island states live near some source of mercury pollution such as a waste disposal site, industrial emissions or polluted waterway yet reported a much lower mercury body burden. The participating women from Tajikistan all lived within a few kilometres of Minamata Convention Annex D mercury emission point sources (cement plant and thermal power station). Women of the Jalari community in Nepal (location 1) consume fish from a waterway contaminated with effluent from medical waste and dental facilities which are a potential mercury pollution source.

The exception to this was a group of women from location 2 in Nepal who live in an urban environment but work in the manufacture of gold plated idols for religious purposes. The method of gold plating known as mercury gilding involves the use of mercury which could be a potential cause of the higher body burden of mercury among some members of this group of

2 Silbernagle, et al, (2011) Recognizing and Preventing overexposure to Methylmercury from Fish and Seafood Consumption: Information for Physicians. J Toxicology 2011;2011 983072

3 US EPA (1997) Mercury study report to Congress, Volume IV, An assessment of exposure to mercury in the United States, EPA-452/R-97-006

4 Trasande L, Landrigan PJ, Schecter C (2005) Public health and economic consequences of Methyl Mercury Toxicity to the Developing Brain, EnvironHealth Perspect 113:590-596

5 Grandjean P, Weihe P, White RF, Debes F, Araki S, Yokoyama K, Murata K,Sorensen N, Dahl R, Jorgensen PJ (1997) Cognitive deficit in 7-year-oldchildren with prenatal exposure to methylmercury. Neurotoxicol Teratol
19:417-428

6 Murata K, Weihe P, Budtz-Jorgensen E, Jorgensen PJ, Grandjean P. (2004) Delayed brainstem auditory evoked potential latencies in 14-year-old children exposed to methylmercury. J Pediatr 144(2):177-183

women and is discussed further in section 3.1.1. The results from location 1 in Nepal (fisherfolk) are much lower, with most samples below the 1ppm reference level, despite the fact that these women, as fisherfolk, have a relatively high fish diet derived from polluted waterways.

1. INTRODUCTION

The adoption of the Minamata Convention on Mercury (in October, 2013) illustrates that the global community recognizes mercury as a global threat to human health, livelihoods, and the environment and is now prepared to commit to further action to reduce global exposure to mercury.

IPEN was closely engaged with the negotiations leading up to the adoption of the Minamata Convention and conducted a range of mercury related enabling activities, released publications and developed awareness campaigns that included mercury monitoring and biomonitoring. An important collaboration for IPEN has been the partnership with the Biodiversity Research Institute (BRI), a non-profit ecological research group with more than 25 years of experience assessing emerging threats to wildlife and ecosystems and is a leader in ecological research related to mercury toxicology.

Mercury monitoring can play a key role in providing an impetus to ratify the Minamata Convention. Additionally, governments have also agreed on the need for evaluating the effectiveness of the treaty and it is recognized that such effectiveness evaluation will have, as one component, the consideration of comparable monitoring data as agreed by the governing body of the Convention, the Conference of the Parties.

In 2014, IPEN launched the International Mercury Treaty Enabling Program (IMEAP), with the aim of supporting preparations for developing countries and countries with economies in transition for rapid ratification and early implementation of the Minamata Convention on Mercury. IPEN successfully initiated activities in 29 countries. Through this process member organizations communicated to IPEN the need to conduct targeted mercury biomonitoring to address widespread data gaps, to further elevate mercury awareness and promote ratification of the Minamata Convention.

In 2015, IPEN proposed a pilot mercury biomonitoring programme to UN Environment focusing on vulnerable sub-populations identified in the Convention's preamble, as well as Article 16 (Health aspects), Article 18 (Public information, awareness and education), Article 19 (Research, development and monitoring), Article 22 (Effectiveness evaluation) and Annex C - Artisanal and small-scale gold mining (ASGM) National Action Plans (NAPs) of the Treaty. In many developing and transition countries there is a paucity of mercury biomonitoring data with which to inform policy decisions and generate public awareness about the hazards of mercury exposure.

IPEN, through its earlier mercury biomonitoring project collaboration[7] with BRI, gained valuable insights into potential locations for monitoring while building capacity within its network to implement a broader range of monitoring activities. In consultation with UN Environment, the IPEN/BRI Project Team determined that there was a need to focus on the generation of data from the Asia and the Pacific region with a particular emphasis on Pacific Small Island Developing States.

Having established the target region for sampling IPEN, BRI and UN Environment extended their cooperative approach to the development of a detailed methodology for the sampling activity which included a background brief on the project to orient IPEN participating organisations who would conduct the sampling, templates of key documents such as consent forms, questionnaires and data log sheets. The methodology also included a detailed sampling protocol to demonstrate how to take the samples safely, avoid cross contamination and prepare the samples for shipment to the laboratory with tracking documentation. The methodology documentation also included a fact sheet to provide contextualised feedback to the participants on the results of their sample analysis, implications for their health and potential mitigation measures they may take to avoid or reduce further mercury exposure.

All of the documentation included in the draft methodology was reviewed by BRI laboratories and UNEP and after consultation between all parties it was released in its final form at the outset of the monitoring program. Key parameters agreed in this consultation phase included the content of the questionnaire, reference levels to be communicated to participants, sampling techniques, shipping and data collection.

In terms of distribution of sampling location types the pilot study was not narrowly defined but had sufficient scope to allow for sampling that reflects typical urban settings that may result in industrialised society exposures as well as remote locations such as Pacific Islands which are more likely to reflect diffuse global mercury pollution that impacts on marine food webs. Further details on the locations for sampling are discussed under section 3 of this report.

7 Evers, D. et al (2014) Global mercury hotspots: New evidence reveals mercury contamination regularly exceeds health advisory levels in humans and fish worldwide. Biodiversity Research Institute. Portland, Maine. IPEN. Göteborg, Sweden. BRI-IPEN Science Communications Series 2014-34. 20 pages.

The wide variety of contexts in which sampling has been conducted is reflected in the disparity of the sampling results which range from low levels in some locations to highly elevated levels in others. The description of sampling locations, results and interpretations of the finding are discussed further below.

2. METHODOLOGY

In preparation for the implementation of this project IPEN and BRI, in consultation with UNEP, developed a methodology based on the framework for sampling previously utilised by IPEN/BRI in their 2014 global study of mercury in fish and hair[8]. The methodology takes into account scientifically sound and acknowledged human hair monitoring protocols including both technical and practical matters as well as an ethics review by the Institutional Review Board by the University of Southern Maine in Portland, U.S. The methodology covers sampling method, collection of data, and mercury measurements as well as assessment and evaluation of the result.

2.1 SAMPLING METHOD

2.1.1 Target Group

The focus of this project is the vulnerable sub-population group, 'Women of child-bearing age in the Asia and the Pacific Region'. The definition of child-bearing age differs to some degree between various institutions. Studies undertaken by United States researchers use the age range of 18-44 years due to Federal government limitations on sampling of biological material from minors. For this project the target group for sampling is women of child-bearing age from 18 to 44 years as it would allow comparison with other studies using this range while meeting legal requirements

2.1.2 Participant Selection

Female participants were selected based on the criteria of (1) their age (18-44 years), (2) willingness to participate, and (3) having sufficient hair to provide a sample for analysis. IPEN Participating Organisations identified and convened participants at each location to administer the consent forms, questionnaire, and conduct hair sampling according to the specified protocols. The participating organisations gathered samples in a scientifically sound manner that is consistent with recognized standards for sample collection of human hair for mercury monitoring[9]. Due to the limited size of this survey, resource constraints and time limitations it was not possible to randomly select participants, establish control groups and

8 Ibid. at p. 18 Appendix

9 United Nations Environment Programme and the World Health Organization (UNEP/WHO), (2008) Guidance for identifying populations at risk from mercury exposure.

balance age sub groups therefore the results do not allow generalization to overall mercury levels in the country population and will not be able to produce results of statistical significance. They do however provide valuable input for potentially prioritising locations for further, more detailed studies designed to allow extrapolation to population level data. Participants were selected on the criteria above and locations where sampling took place were based on advice from IPEN participating organisations who considered issues of access, cultural sensitivities, timing and cooperative approaches with local communities and civil society organisations who supported the sampling.

2.1.3. Ethics review and confidentiality of participants

Prior to implementing this sampling project the overall methodology was reviewed and approved by the Institutional Review Board of the University of Southern Maine in the U.S.A. to ensure it met contemporary standards for ethical implementation of studies involving human subjects.

The sample collection protocol incorporated elements consistent with this approval with supporting documentation. Participants were asked to sign a consent form if they were willing to have a hair sample collected for analysis. A questionnaire was then administered to the participant by the IPEN organisation representative supported by a local, native speaking volunteer to ensure that the process was understood by participants and that accurate information could be collected from the questionnaires. Where English was not an appropriate language, participants were provided with a translation of relevant documentation, including waivers, questionnaires and sample results.

The right of confidentiality was granted to each individual participant unless she voluntarily decided to sign a document to waive it. To protect confidentiality of participants a number of controls were implemented. Project related data is presented as an aggregated analysis that does not enable public identification of individual participants. Each hair sample shipped to the BRI laboratories was labelled with an individual sample ID code and country location code so that BRI is does not have access to the identity of individual sampling participants. The same ID code is affixed to the front page of each completed questionnaire allowing the data from questionnaires to inform the interpretation of sample analysis by IPEN without compromising confidentiality. The IPEN organisation that conducted sampling holds the master list linking the ID code to the name of the participant to allow them to provide contextual health related feedback to the individual participant along with the results of their individual hair sample analysis for total mercury concentrations.

Once individual participant sample data is generated and communicated back to the participant, that individual has the right to release that information if she chooses to do so. This is consistent with an individual's right to know about their personal health information and disclose it if they wish to.

2.1.4. Sample collection protocol

All IPEN POs tasked with coordinating the collection of samples were provide with detailed sample collection, packaging and shipping protocols to ensure minimisation of any cross-contamination and to standardize sample collection for comparative analysis.

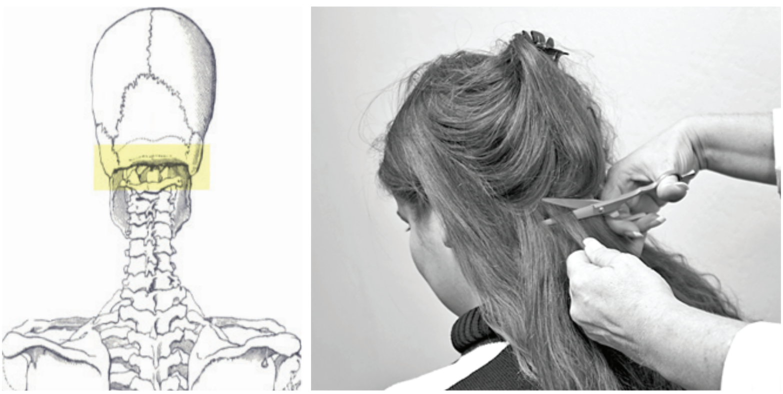

Figure 1. Occipital Region: Target sample area

Figure 2. Correct labelling and storage of sample

Before taking a sample the participant was invited to sign the consent form. If the participant declined, no sample was taken. After the participant signed the consent form the sampler then administered the questionnaire. Following the completion of documentation the sampler, while wearing a pair of nitrile examination gloves (for collecting and handling each sample) would use an alcohol wipe to clean the cutting surfaces of the stainless steel scissors for cutting the hair sample.

Hair samples were obtained from individuals by cutting a small bundle of hair approximately 8-10cm long and the thickness of a pencil (about 30 hair strands) from the occipital region of the skull as close as possible to the scalp.

The hair sample was then secured with a small self-adhesive label using an arrow to indicate the direction of the scalp leaving 3-4 cm of hair exposed from the label.

2.1.5. Sample analysis – mercury measurement

Once correctly packaged and labelled the samples were shipped by courier along with a data sheet listing each sample origin and a corresponding sample ID code. As soon as shipments arrived in the U.S. the hair samples were analyzed for total mercury at BRI's Wildlife Mercury Research Laboratory following EPA method 7473 by gold-amalgamation atomic absorption spectroscopy following thermal desorption of the sample using a Milestone DMA-80. A blank and two calibration standards (DORM-3 and DOLT-4) are used in each of the two detector cells. Instrument response are evaluated immediately following calibration, and thereafter, following every 20 samples and at the end of each analytical run by running two certified reference materials and a check blank. Instrument detection limit is approximately 0.050 ng. An acetone wash of the hair samples followed by a rinse with milli-Q water can be used to remove external contamination, such as hair products. Results of total mercury are then recorded for each sample in parts per million (ppm) and recorded in tables by location.

2.1.6. Assessment of results

The interpretation of sample results will be based on the comparison of data generated from the field samples with a reference level of 1ppm which equates approximately to the U.S. EPA's reference dose for mercury in human hair (USEPA 2001). Mercury concentrations above 1.0 ppm in hair have been related to neurological impairments in adults[10]. These data

10 Yokoo et al. (2003); Karagas et al. (2012)

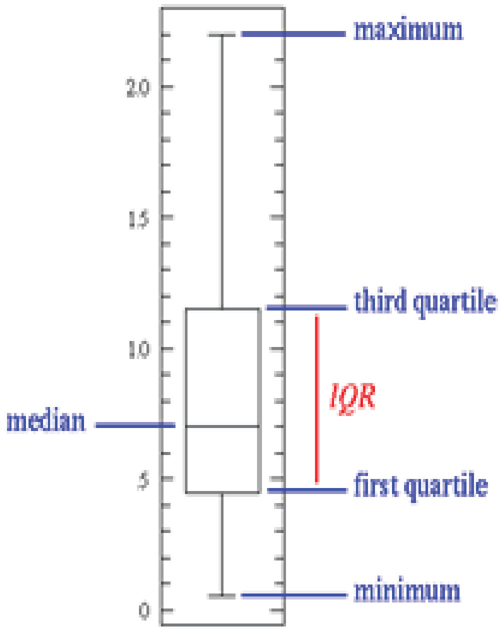

Figure 3. Box Plot example. *Source: St John's University, Minnesota, U.S.A.*

will help determine contaminant concentrations in participating human subjects and potentially identify regions that require more intensive investigation. Presentation of the data is explained below.

Figure 3 explains the chart features for a box plot (also known as a 'box and whisker plot'). The example on the left notes the key features of a box plot which shows the distribution of data from minimum, first quartile, median, third quartile, and maximum. The 'box' shows the interquartile range or IQR. The line inside the 'box' shows the median of the data set while the 'whiskers' above the box show maximum values and below show minimum values. On the combined box plot chart in section 4 each location is represented by an individual box plot.

Additional information is included on the combined chart in section 4 (Fig. 4).

In Figure 4 locations are arranged by mean from left to right with the blue asterisk representing the mean for each location. The red points denote outliers[11] and the dashed line represents the 1ppm reference level.

11 Outliers are defined as values 3 times the interquartile range or more above the third quartile or 3 times the interquartile range or more below the first quartile.

3. SAMPLING LOCATIONS

Based on the limited financial resources and the diversity of geographic landscapes and populations, IPEN identified countries and a number of locations for sampling, below, for NGOs to identify women of child-bearing age participants to take part in this study. A pre-requisite for sampling was granting of the necessary approval from the national authorities of participating countries. Obtaining authorisation to conduct sampling proved very challenging and constrained the number of countries where the sampling projects could be carried out. In addition to the countries listed below many others were approached and invited to participate however government officials chose not to take part in the study or were non-responsive.

Those countries which agreed to participate and where sampling was successfully conducted are listed in Table 1. The selection of locations within these countries is not necessarily associated with known mercury contaminated sites and are predominantly urban locations. In the case of the Pacific Islands where sampling occurred, there is very little industrialisation or related pollution although there are landfill and other waste management infrastructure. The elevated results from these locations is subject to further discussion under section 5.

TABLE 1. SAMPLING LOCATIONS IN THE ASIA AND THE PACIFIC REGION

Country	Population	Locations sampled	Samples collected
Cook Islands	17,794(2011 census)	2	60
Kiribati	103,058*	1	30
Nepal	26,494,504 (2011 census)	2	53
Republic of Marshall Islands	68,480**	1	30
Republic of Tajiki-stan	8,551,000***	1	31
Tuvalu	10,837 (2012 census)	1	30

*   *Source: Government of Kiribati Statistics Agency*
**   *Source: Government of Marshall Islands*
*** *Source: Republic of Tajikistan, Agency of Statistics current estimate.*

3.1 SAMPLING LOCATION DESCRIPTIONS

3.1.1 Nepal

Sampling in Nepal was conducted in two locations. The first location was among the Jalari community of fisherfolk in the Begnas Lake area of Pokhara, Nepal. The second location was an urban area in the Lalitpur District of the Kathmandu Valley.

Location 1: Women of the Jalari community near Begnas Lake. The Begnas Lake is the second largest lake in Pokhara city of Nepal receiving a lot of agricultural runoff, city drainage and waste from health care centres including dental clinics. The Jalari community are a genuine fisherfolk community who live nearby and are dependent on this lake for fishing for their livelihood and consume those fish least preferred by customers in particular a species called Tilapia (predatory fish) with least commercial value.

Location 2: Women of the Lalitpur District of the Kathmandu Valley.This is an urban area typical of those around major cities in Nepal. Women who participated in sampling are engaged in religious idol manufacture (including a process of mercury based gold plating), domestic tasks and associated urban activity. . The gold plating process known as mercury gilding has been used for over 2000 years[12] and involves mixing of metallic mercury and gold particles to form a paste which is applied to the idols. The mercury is then burned off leaving a gold coating. This activity results in mercury vapor exposure of workers who are engaged in this process. Some workers may also directly handle mercury. The levels of total mercury measured in the hair of some of these workers is at similar elevated levels to Tanzanian artisanal and small scale gold miners who are directly engaged in burning mercury gold amalgam for extended periods[13]. The occupational exposure of mercury gilders to mercury vapor has not been extensively studied however one recent study[14] concluded that acute mercury intoxication arose among a group of gilders using this technique to gold plate a shrine suggesting this technique is a plausible exposure route leading to elevated hair mercury concentrations among the workers sampled in Nepal.

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12 Giumlia-Mair et al (2014) *Mercury Gilding in Today's Japan: An Amalgam of Old and New.* ISIJ International Vol. 54 (2014) No. 5 p. 1106-1110

13 Evers, D. et al (2014) *Global mercury hotspots: New evidence reveals mercury contamination regularly exceeds health advisory levels in humans and fish worldwide.* Biodiversity Research Institute.

14 Vahabzadeh M, Balali-Mood M. (2016) *Occupational metallic mercury poisoning in gilders.* Int J. Occup Environ Med 2016: 7-122

3.1.2 Tajikistan

Sampling was conducted in urban areas of Dushanbe which is the capital city of Tajikistan. Participants live close to the Varzob River where they catch fish for personal consumption. There are some sources of mercury pollution in the area such as the Dushanbe Thermal Power Plant (TPP) which was commissioned in 2013. The facility uses coal from the Ziddi coal field located in the upper stream of the Varzob River. The old cement production plant is located near the TPP and consumes coal from the same coal mining field. *Cement plants and Thermal Power Plants based on coal are listed as point sources of emissions of mercury and mercury compounds in Annex D on the Minamata Convention.*

3.1.3 Cook Islands

The nation of Cook Islands are a remote group of 15 South Pacific islands spread over 2.2 million square kilometres. Sampling was conducted in two locations in the Cook Islands group.

Location 1: Sampling was conducted in Rarotonga among women who were originally from other villages in Rarotonga or islands in the Cook Island group.

Location 2: The second location for sampling in Cook Islands was among office workers based in Rarotonga.

3.1.4. Tuvalu

Tuvalu is a nation of nine islands in the southwest Pacific Ocean formerly known as the Ellice Islands. They have a combined land mass of 27 square kilometres. Around 94% of the ethnic Tuvaluan population are Polynesian. Those on the island of Nui are of Micronesian origin. Sampling was conducted in Funafuti Island, the administrative capital of Tuvalu. Women who participated were from a range of Tuvaluan islands.

3.1.5 The Republic of Kiribati

The Kiribati islands consist of three main groups separated by long distances in the southwest Pacific Ocean. The three groups are the Gilbert group on the equator, the Phoenix Islands in the east and the Line Islands further east. The total land mass is 811 square kilometres. Participants in the sampling project were from the Betio district of the capital island Tarawa.

3.1.6 The Republic of Marshall Islands

The Marshall Islands is a nation of 29 coral atolls and 1,156 islands and islets in the Pacific Ocean located close to the equator just west of the international date line. Sampling was conducted in the capital Majuro which has a population of around 27,800 people who are predominantly Micronesian.

4. RESULTS OF SAMPLE ANALYSIS AND QUESTIONNAIRES

4.1 HAIR SAMPLE ANALYSIS

The results of analysis of hair samples for Total mercury (THg) in all countries are provided at Table 2 and include the cohort mean with one standard deviation.

TABLE 2. RESULTS OF HAIR ANALYSIS FOR THG OF WOMEN OF CHILDBEARING AGE IN THE ASIA AND THE PACIFIC REGIONS

Country	Average THg (ppm) in Hair	St. Dev.	Max. THg (ppm)	Min. THg (ppm)	Sam-ple Size
Cook Islands loc. 1	3.60	1.67	6.96	0.17	30
Cook Islands loc. 2	3.67	2.19	8.51	0.96	30
Kiribati	3.42	1.27	7.51	1.77	30
Nepal loc. 1	0.67	0.24	1.18	0.21	33
Nepal loc. 2	3.62	6.11	28.46	0.35	20
Rep. Marshall Islands	3.25	2.2	11.31	0.55	30
Rep. Tajikistan	0.06	0.12	0.70	0.01	31
Tuvalu	1.99	0.64	3.40	0.53	30

4.2 AGE RELATED DATA

The women who consented to taking part in the hair sampling activity were drawn from the age bracket of 18-44 year olds to correspond with one of the most vulnerable sub-set of women – those of childbearing age. While it is common that women give birth to children outside of this age range this range was selected as it a broadly utilized range in the scientific literature and allows for comparison to other studies. There was also a limitation of the study that samples from minors (aged less than 18 years)

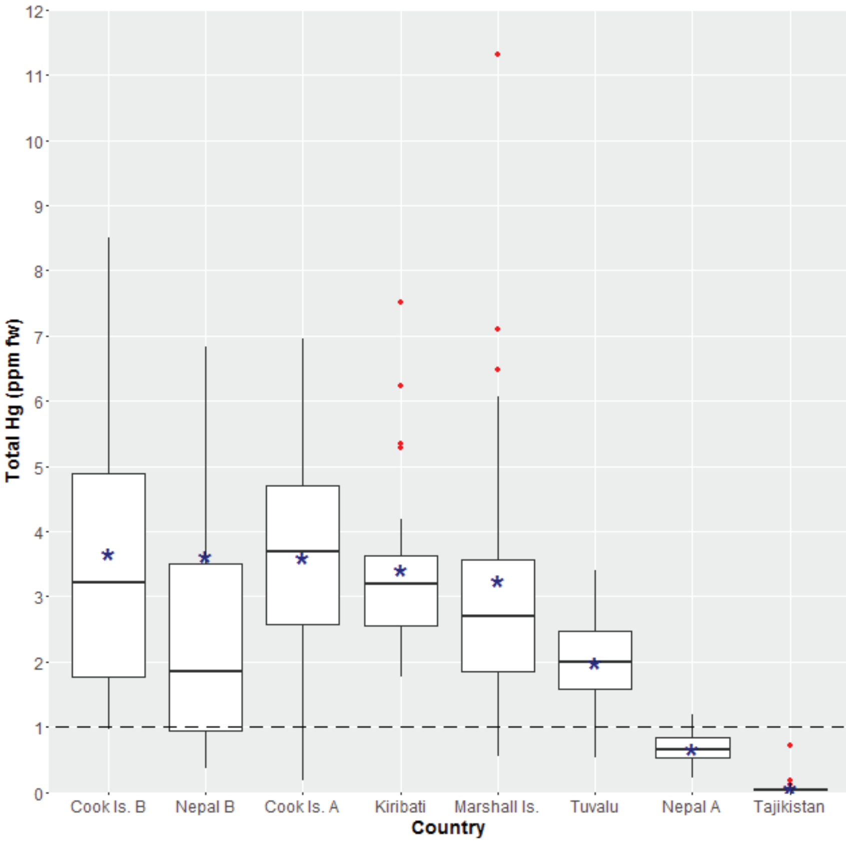

Figure 4. Mercury concentrations in hair (ppm fw) in human hair by location.
Note: Dashed line represents the 1 ppm total mercury reference level. A single outlier of 28.5 ppm from Nepal B (location 2) could not be included on the box plot due to scale limitations.

are not legally permitted to be analysed at US laboratories due to ethical considerations.

This study did not seek to balance the age sub-categories in this study (the sub categories for analytical purposes were 18-25, 26-30, 31-35, 36-40, and 41-44 years old) as timing and logistical constraints usually ensured there was not a surplus of volunteers. IPEN samplers therefore accepted participants that fell within the study age range without attempting to balance age related sub categories which may have resulted in some potential volunteers being rejected as participants due to all positions in their sub-

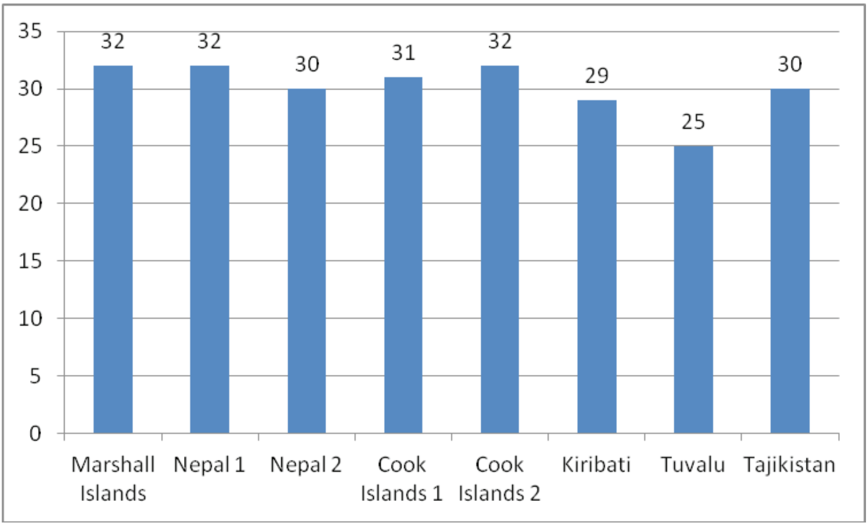

Figure 5. Average age of sampling participants by location.

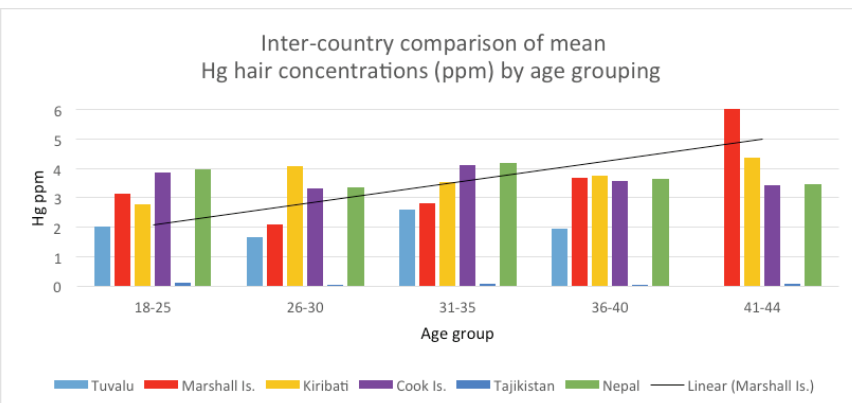

Figure 6. Inter-country comparison of mean Hg concentrations by age grouping.

category being filled. For this reason some locations have a larger number of women in one age sub category than another. These variables impact on the degree of certainty associated with age related trends presented below.

Relevant data from the questionnaires was compiled to see if there were any trends indicating that mercury was accumulating in the participants

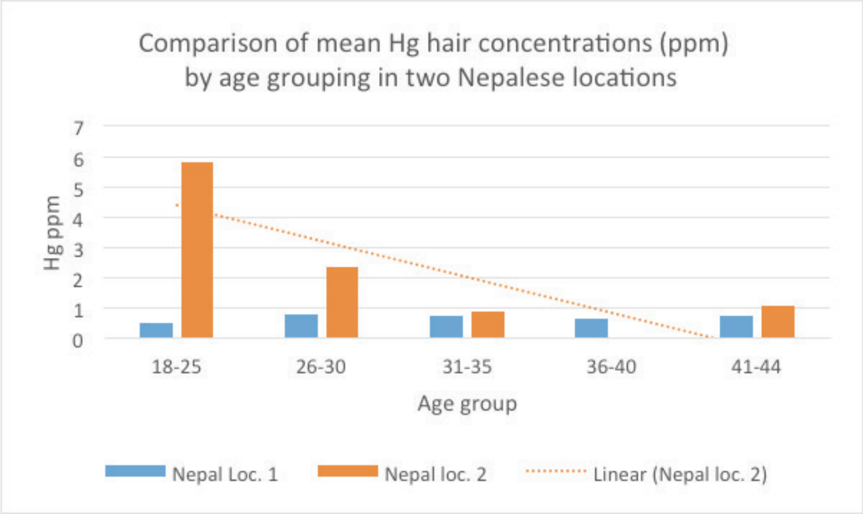

Figure 7. Comparison of mean Hg hair concentrations (ppm) by age grouping in two Nepalese locations.

over the age range related to the study (18-44). The results in Figure 6 do not indicate an age related increase in hair mercury concentrations for most locations with the exception of the Marshall Islands where a distinct upward trend in mercury concentrations with age was evident. However, the number of women in each age bracket within each location was relatively small, unbalanced between groups and in some cases (Tuvalu 41-44 years; Nepal location 2 36-40 years) there were no women in a particular age grouping, all of which are variables that affect the results and interpretation. A larger study in each location with an age balanced participant selection would be valuable to assess this trend in a more consistent manner.

The results in Figure 6 include an aggregate of the data from location 1 and 2 in both the Cook Islands and Nepal. While the mean mercury levels, when compared between location 1 and 2 in the Cook Islands, varied slightly, the mean mercury levels compared between location 1 and 2 in Nepal differed significantly and have been presented separately in Figure 7 for consideration. Additional variables which were not collected as data include the length of time that an individual resided in a given location. Depending on the mercury exposure scenario, length of residence in a given location could be a significant factor.

When comparing the results for location 1 and 2 in Nepal (Figure 7) the trend is quite different to that observed in the Marshall Islands (Figure 6) with an inverse relationship between age and mean mercury concentrations by age group in Nepal location 2 but with no discernable trend in Nepal location 1.

A number of factors affect the results of the intra-country comparison for Nepal. Nearly all women from location 1 (who have a fish rich diet) had mercury hair concentrations below the 1 ppm reference level and had a more balanced distribution (18-25 n=6, 26-30 n=8, 31-35 n=7, 36-40 n=5, 41-44 n=4) within each age group than location 2 (18-25 n=10, 26-30 n=3, 31-35 n=1, 36-40 n=0, 41-44 n=6).

While these variables may help explain the age related trends, the bias in terms of participant numbers toward the youngest age group in location 2 doesn't explain the significantly elevated mean hair mercury concentrations in the youngest group compared to older women from this location. The questionnaire data for location 2 indicated that most of the older women have worked in the mercury gilding occupation for many years or even decades suggesting their level of exposure and accumulation of mercury may be higher than the younger women in this occupation. However, the younger women have a mean mercury concentration five times higher than the older women indicating that other variables may be responsible.

More information about the nature of the occupational exposure of mercury gilders from location 2 is required to assess this phenomenon. It may be that the older women are engaged in administrative duties and are less exposed to mercury vapors and that the younger women have a more direct role in preparing, handling and applying the mercury-gold amalgam paste and hence more exposure to mercury. A site specific assessment of the gilding operation would increase our understanding of roles and exposure of the employees in this activity.

4.3 DIETARY DATA

Participants in the sampling program were also asked to provide a range of details in their questionnaire related to their diet. In particular these questions focused on the amount of fish in their diet, frequency of consumption and the species consumed most often. Although the limitations of this study (e.g. fish were not sampled for mercury concentrations in this study) preclude a detailed statistical analysis some inferences can be drawn about the levels of fish consumption, the species consumed and the hair concentrations of the participants.

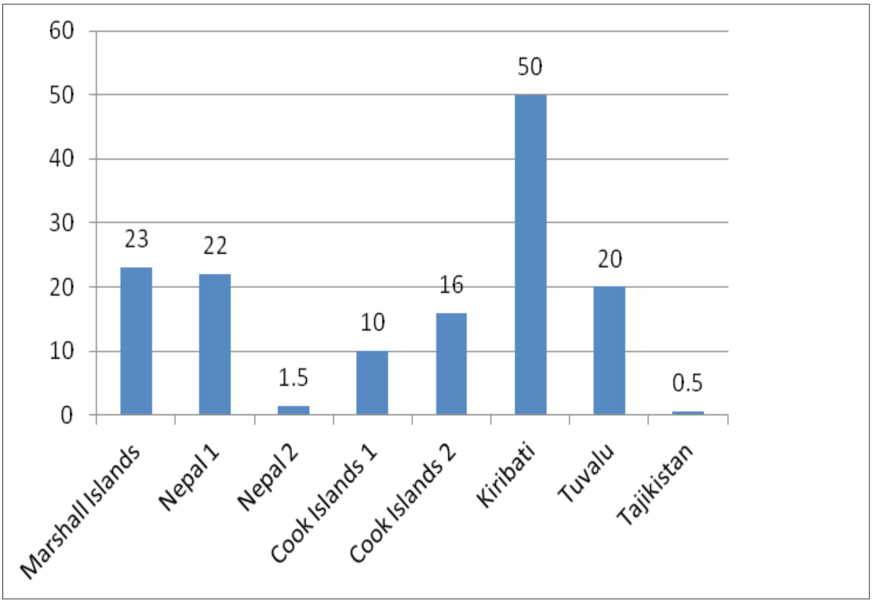

Figure 8. Average fish meal consumption per month by location.

Considering the results of hair sampling presented in this report there appears to be a strong relationship between the amount of fish and type of species consumed in the Pacific Island nations and the elevated levels of mercury in the hair of those women. Women in these countries are eating more fish than other locations but are also eating higher levels of fish from higher trophic level species known to accumulate mercury to levels that may impact human health such as tuna species, marlin and swordfish. A lack of possible industrial sources of mercury pollution in the Pacific Islands strengthens this correlation.

In Tajikistan fish consumption and mercury hair concentrations were both low. However in Nepal location 1 participants have a high fish diet but low mercury hair concentrations and conversely at location 2 women have a low fish diet with elevated mercury hair concentrations. This may be explained in part due to the occupational mercury exposure of women at location 2 in mercury gilding activity.

The low mercury hair concentrations at location 1 may be related to low concentration of mercury in the Tilapia fish they consume but this should be confirmed with fish sampling data before any definitive conclusion can be made.

Figure 8 demonstrates the significantly higher consumption of fish by Pacific Island women compared to respondents from other locations (with the exception of Nepal location 1).

Respondents were also asked to describe the primary fish species that they consumed to provide some contextual data as to whether their diet was high or low in higher trophic level species known to have higher mercury concentrations in their flesh. The results are presented by location below and discussed further in section 5.

MARSHALL ISLANDS

Average age: 32
Average consumption of fish meals per month: 23

Most of the respondents were employed in the tourism and hotel industry (waitress, home duties). Others worked on administrative positions.

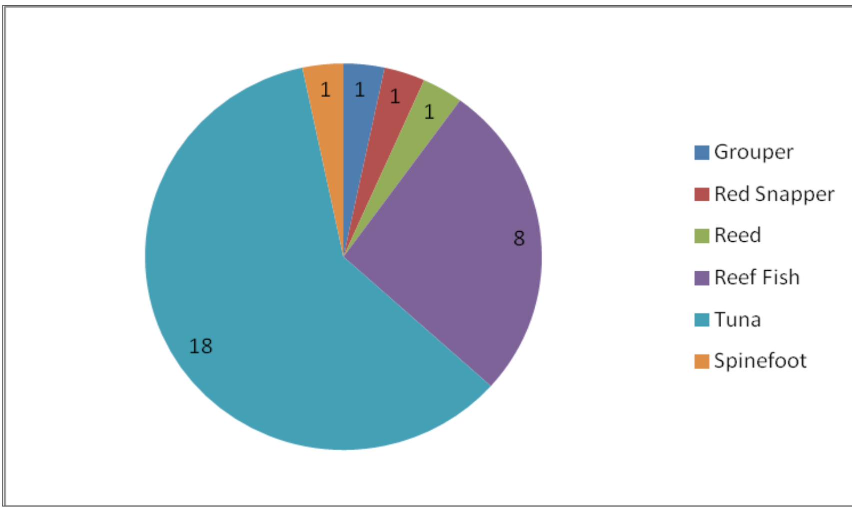

Figure 9. Primary fish species consumed - Marshall Islands.

NEPAL – LOCATION 1

Average age: 32
Average consumption of fish meals per month: 22

Predominant occupation is fisherwoman, but some respondents were also employed in agriculture, tourism, education and one in the chemical industry. None of the respondents was aware of occupational mercury exposure except for one chemical factory worker.

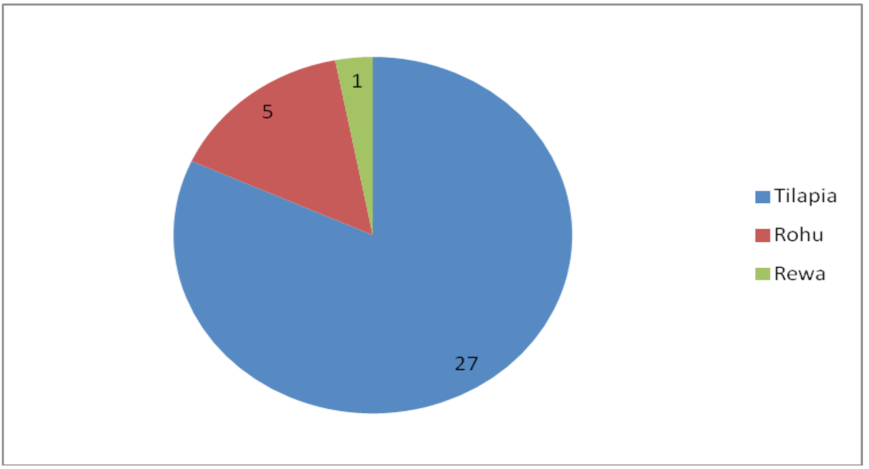

Figure 10. Primary fish species consumed - Nepal location 1.

NEPAL – LOCATION 2

Average age: 30
Average consumption of fish meals per month: 1-2

All respondents work in mercury based gold plating facility and already avoid fish consumption. On the other hand, none of them is aware of the type of exposure to mercury from gilding.

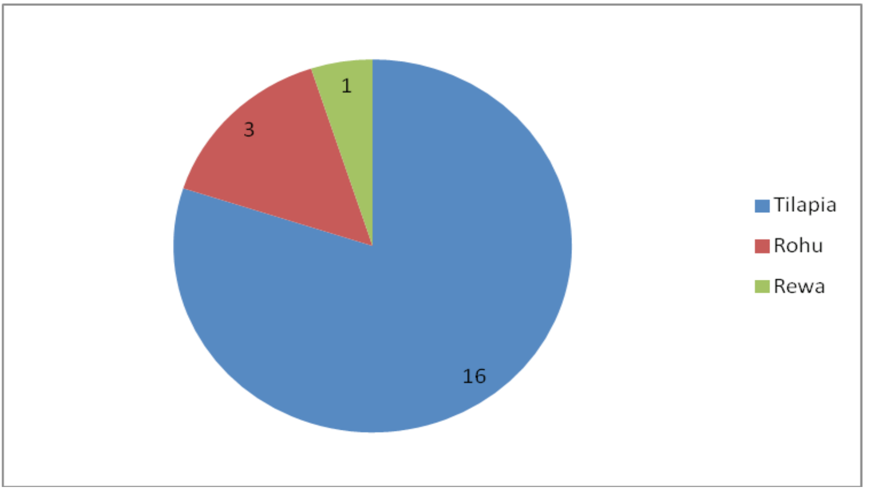

Figure 11. Primary fish species consumed - Nepal location 2.

COOK ISLANDS – LOCATION 1

Average age: 31
Average consumption of fish meals per month: 10

Respondents were predominantly employed in the office environments and none of them was aware of any occupational exposure to mercury or source of mercury pollution and 20 percent of respondents already limit fish consumption.

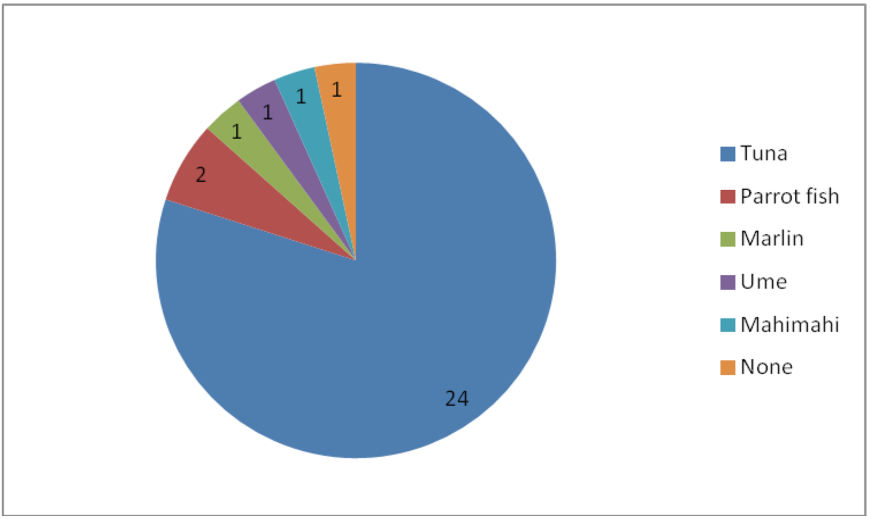

Figure 12. Principal fish species consumed - Cook Islands location 1.

COOK ISLANDS – LOCATION 2

Average age: 32
Average consumption of fish meals per month: 16
Average consumption of fish meals per month: 15-16

All respondents were office workers or government employees. None of them has been limiting the intake of fish meat because of possible mercury contamination. None of them was aware of source of occupational mercury exposure or a close source of mercury pollution.

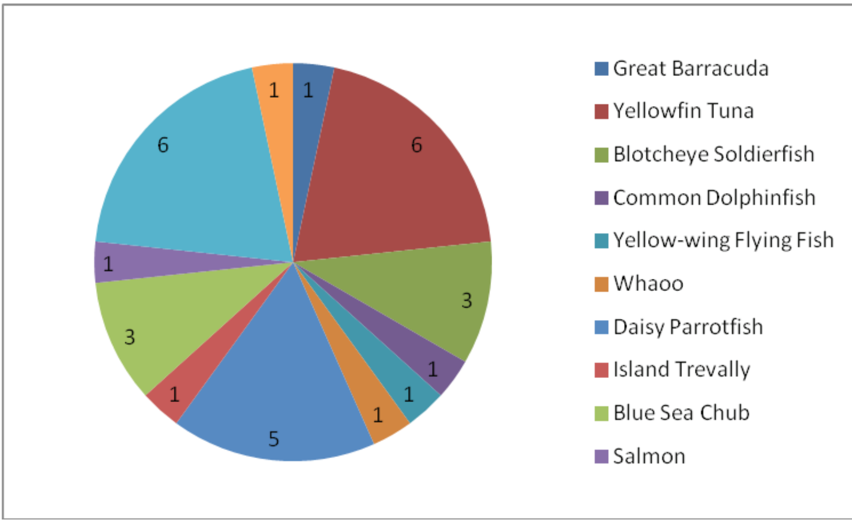

Figure 13. Principal fish species consumed – Cook Islands location 2.

KIRIBATI

Average age: 29
Average consumption of fish meals per month: 50

The respondents' occupation was mainly fish sellers or house duties. Also other occupations included student, teacher or retired. One of the respondents limits the consumption of fish meals due to mercury contamina-

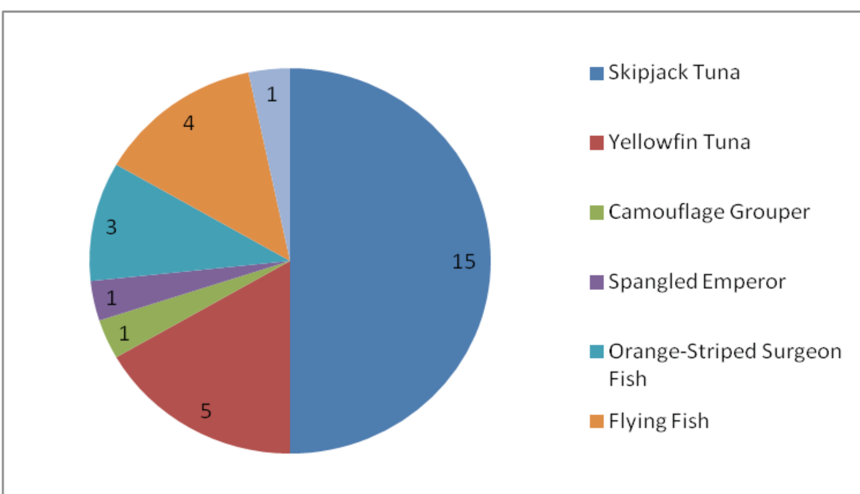

Figure 14. Principal fish species consumed - Kiribati.

tion. None of them was aware of any occupational exposure to mercury or source of mercury pollution.

TUVALU

Average age: 25
Average consumption of fish meals per month: 20

The respondents worked mainly in the tourism / hotel industry. One of the respondents limits the consumption of fish meals due to mercury contamination. None of them was aware of any occupational exposure to mercury or source of mercury pollution.

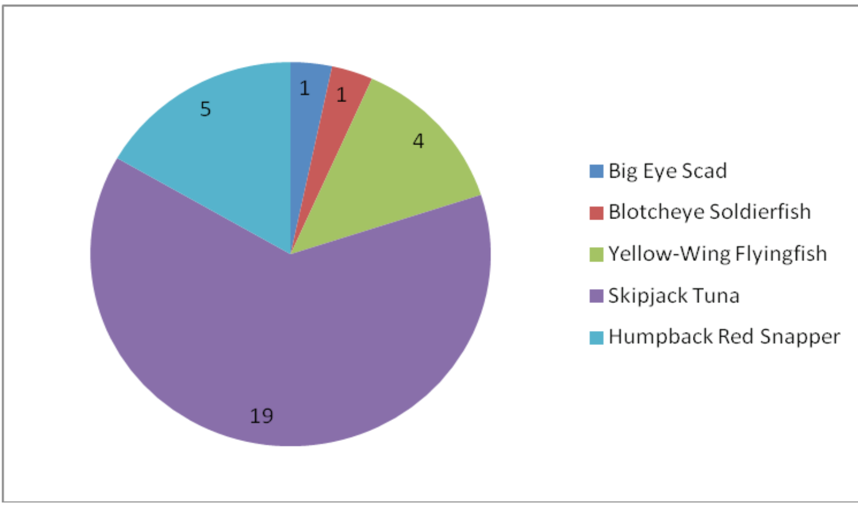

Figure 15. Primary fish species consumed - Tuvalu.

TAJIKISTAN

Average age: 30
Average consumption of fish meals per month: 0-1
(collected data was limited, so this was determined based on data on primary fish consumption)

Majority of respondent's occupations were reported as students, home duties, hospital workers, teachers or were in the hotel industry. None of them avoided fish consumption due to mercury pollution. Only one respondent (nurse) was aware of occupational mercury exposure and a close source of mercury pollution.

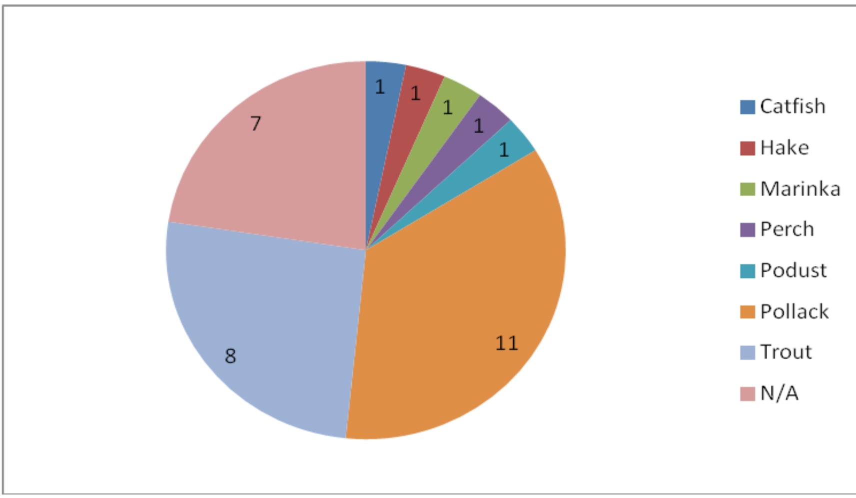

Figure 16. Principal fish species consumed - Tajikistan.

5. ASSESSMENT AND DISCUSSION

Examining the results of the hair sampling data among women of child-bearing age in selected countries of the Asia and Pacific Region allows a number of observations. The graphic representation above shows a clear trend toward highly elevated levels of mercury among women of the Pacific Islands where sampling has taken place. Using the reference level of 1ppm (represented in Figure 4 as the broken horizontal line) agreed in the project methodology as the threshold below which health effects are currently deemed negligible, it is clear that the average THg levels for Pacific island women are well above the reference level.

In Nepal, at location 1, the average levels of mercury in women's hair was 0.67ppm ± 0.24 ppm (fw) and only 9% of those sampled exceeded the 1ppm reference level . At location 2, the average levels of mercury in women's hair was 3.62 ppm ± 6.11 ppm (fw) and 75% exceeded the 1 ppm reference level. The women from location 1 in Nepal are fisherfolk who eat the catch that is least marketable but mostly had mercury levels below 1 ppm, however women from location 2 were mostly engaged in the manufacture of gold plated religious idols in their township. This ancient method of gold plating or mercury gilding involves creating an amalgam paste of mercury and gold dust which is applied to the idols and then heated to drive off the mercury as vapor. As a result the data suggests that most of these women are exposed to high levels of mercury vapor in a similar scenario to that of ASGM workers employing the mercury amalgam technique to recover gold as described in section 3.1.1.

Despite Nepalese women of the Jalari fishing community (location 1) consuming fish regularly in relatively high quantities compared to women from location 2 in Nepal, they do not have elevated mean hair mercury levels. The women from location 2 who are engaged in mercury gilding as an occupation have a mean mercury hair levels more than five times higher suggesting both occupational exposure to mercury vapour among the gilders and a relatively low level of mercury contamination among the species of fish eaten by the Jalari women.

Given the relatively high fish consumption by both Jalari women from Nepal and most participants from the Pacific Island states (who are not subject to occupational exposure, industrialisation or Annex D sources) it is notable that the levels of mercury in hair of Pacific Islands are particularly elevated. An inference may be drawn that the fish consumed in the pacific islands have a much higher concentration of mercury than those in Begnas Lake. This could be confirmed with additional biomonitoring of fish stocks in the lake, especially the Tilapia (Oreochromis niloticus) which are the mainstay of the Jalari fish diet.

In Tajikistan, where fish is not often eaten, the levels of mercury were very low with an average mercury level in human hair of 0.068 ppm ± 0.12 ppm (fw). None of the participants had a total mercury level exceeding 1 ppm with the highest level recorded at 0.70 ppm.

In the Cook Islands 95 % of women had levels above the 1 ppm reference level with the average or mean levels among the cohort exceeding this level by more than 3 fold with a mean level of 3.63 ppm ± 1.91 ppm (fw). Of the group exceeding the reference level 20% of women exceeded the reference level by 5 fold (5 ppm) or more. Four individuals exceeded 7ppm indicating that elevated mercury concentrations are common among Cook Island residents.

Again, in Kiribati 100% of those women providing samples exceeded the 1ppm threshold with all women returning results at least 3 fold higher than the 1ppm threshold. The average mercury level in human hair in Kiribati was 3.42 ppm ± 1.27 ppm (fw). In addition 13% of all participants reported levels in excess of 5 ppm.

In the Marshall Islands 96% of women exceeded the threshold level of 1 ppm where the average level of mercury in hair for the group was 3.25 ppm ± 2.21 ppm (fw). Of this cohort 16% exceeded a THg concentration of 5ppm with one individual registering in excess of 11 ppm.

In Tuvalu 93% of women who provided samples had a THg level in excess of 1 ppm. The average for the group was 1.99 ppm ± 0.64 ppm (fw). Of this cohort none exceeded 4 ppm THg.

Overall 96% of women sampled in the Pacific Islands had a total mercury concentration that exceeded 1ppm and on average their results were between 2 ppm and 3.7 ppm

The clearly elevated levels among women of the Pacific islands appears to be almost entirely due to their diet which is rich in fish, especially higher trophic level predatory fish, which are known to have accumulate significant level of mercury in their tissue. This exposure pathway for elevated mercury levels among the Pacific women sampled is supported through questionnaire data indicating high dietary levels of fish known to carry an elevated body burden of mercury. By comparison most participants of non-Pacific origin, with the exception of the Jalari women in Nepal, had relatively low levels of fish in their diet especially with regard to larger predatory fish species.

This conclusion is further supported by the fact that the Pacific Islands where sampling was conducted lack developed industrial infrastructure known to be a significant source of mercury emissions and releases such as waste incinerators, coal-fired power plants, metallurgy plants, chlor-alkali plants or cement kilns. Artisanal and small scale gold mining (ASGM) activity which is known to have high exposure levels of mercury for many of those engaged in the activity is not practiced on these islands.

With the exception of local landfills, open burning of some waste and exposure to some products containing mercury there is limited exposure to direct mercury pollution that would explain the widespread elevated levels of mercury body burden among these women, some of whom are from very remote outer islands away from urban centres of the Pacific island capitals.

Given the lack of direct exposure to local mercury pollution sources and the extremely wide geographic distribution of participants, it can be concluded that the elevated mercury body burden impacts experienced by the Pacific Island sub-group in this project is attributable to diffuse mercury pollution of the ocean. In turn bioaccumulation and biomagnification of methylmercury among commonly eaten fish species is the most likely route of exposure of the study participants leading to elevated mercury body burden for these women.

While there appears to be a clear trend in relation to elevated mercury levels among women of the Pacific Islands due to fish consumption, further targeted sampling at a scale which would produce statistically relevant population level data should be undertaken. In addition sampling in a broader suite of urban Asian regional areas could be undertaken to strengthen the comparative analysis between Pacific SIDS and their counterparts in Asia to assess the impact of direct industrial pollution exposure on mercury body burden relative to the diffuse mercury pollution which appears to have a pronounced impact in the Pacific.

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