Hair Mercury Levels in the Maldives: Assessing Exposure in a High Fish Dependent Population

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Environmental Management and Conservation Department
Ministry of Tourism and Environment

Country Profile

- Situated in the central part of the Indian Ocean
- Consists of approximately 1,190 low-lying coral reef islands that form 26 natural atolls
- Total area over 90,000 sq kms
- Total population: Approximately 568,362, dispersed across 187 inhabited islands
- Fish/fisheries products: over 98% of the physical exports from Maldives by quantity and value

Status of Mercury in Maldives

- Only source of mercury in the Maldives: Import and transboundary pollution
  - No mining, manufacturing or production of mercury/mercury added products

- Mercury containing products imported into the Maldives (Minamata Initial Assessment, 2019)
  - Batteries, Compact fluorescent lamps (CFL), Dental amalgam, Thermometers, Sphygmomanometers

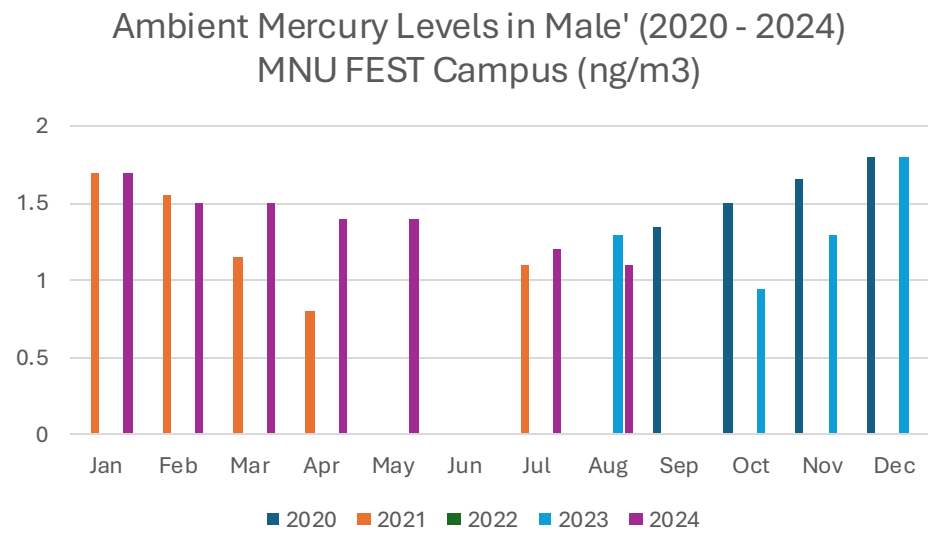
- Mercury release sources (Minamata Initial Assessment, 2019):
  - 84% from 'waste incineration and open waste burning'
  - 15% from 'use and disposal of other products'

- Legal framework on Mercury: No overarching legislation
  - Mercury Free Policy for Health Care 2018 (Policy /23-MOH/2018/01): Hg products phased out from healthcare facilities
  - The Ministry of Climate Change, Environment and Energy are responsible for the Minamata Convention

- Minamata Convention on Mercury ratified by the Maldives in September 2024

Air Mercury Levels

- Sampling location: Maldives National University FEST Campus
- Sampling funded by MOEJ and supported by IDEA Consultants, Japan
- Samples analysed by IDEA Consultants
- Part of the Asia Pacific Mercury Monitoring Network – same day sampling by all countries each month



- Observation:
  - The range of concentration at 0.8 - 1.8 ng/m^3 (average: 1.38 ng/m^3) - within safe levels
  - Slight seasonal variation observed: increase in levels during the dry season. Overall air quality deteriorates in the country during the dry season due to an increase in transboundary air pollution as a result of the winds moving south west from the South Asian continent

Mercury in Fish

- **Fish is the main source of methylmercury worldwide**
- Due to the bioaccumulative and biomagnificative properties of methylmercury, it can build up and increase in concentration up the food chain, resulting in higher levels in predator fish (e.g., Tuna) and benthic species
- Guideline values for different fish species are presented in the table:

Issued	Target	Parameter	Type	Value mg/kg
FAO and WHO (2018)	Alfonsino	MeHg	Maximum level of whole commodity fresh or frozen (in general after removing the digestive tract)	1.5
	Marlin			1.7
	Orange roughy			0.8
	Pink cusk-eel			1.0
	Shark			1.6
	Tuna			1.2
USEPA (2001)	Fish	MeHg	Human health criteria	0.3
USFDA (2000)	Fish, shellfish, crustaceans, other aquatic animals (fresh, frozen or processed)	MeHg in edible portion	Action level	1.0
EU (2006)	Fishery products and muscle meat of fish excluding species listed below except for the followings: brown meat of crab, head and thorax meat of lobster and similar large crustacean	Total Hg	Maximum level in food stuff	0.5
	Muscle meat of fish (species defined*)	Total Hg		1.0
MOHLWJ (1973)	Fish and shellfish except for the followings: Tuna (tuna, swordfish, bonito), Freshwater fish, Demersal fish (sting fish, alfonsino, sablefish, red queen crab, ivory shell, sharks)	Total Hg	Provisional standard	0.4
		MeHg (reference value)		0.3

Fish Samples Analysed by NHL

- The National Health Laboratory (NHL) of Maldives conducts mercury analysis of fish samples upon request by clients (for periodic food quality monitoring by fish exporters/MFDA)
- NHL uses a direct mercury analyzer (DMA-80) (compliant with US EPA method 7473)

- The levels of mercury found in samples analysed by NHL from 2022-2023: levels are below guideline values

Type of Fish	Number of Samples	Mean Hg (mg/kg)	Median Hg (mg/kg)	Maximum (mg/kg)	Minimum (mg/kg)
Tuna	7	0.4004	0.4126	0.8425	0.0867
Humpback Red Snapper	19	0.1607	0.1510	0.2575	0.0635
Bigeye Scad	20	0.0358	0.0272	0.0884	0.0149
Prawn	1	0.0081	0.0081	0.0081	0.0081

Study on Mercury Levels in Fish

Study title: (Abstract from Theveli 2024)

A Preliminary Study on the Difference in Mercury Levels in Humpback Red Snapper as a Biomarker (Moosa & Aishath 2024, The Maldives National University)

- **Sample collection**: From areas where land reclamation projects have been carried out and from areas where no land reclamation has been carried out nearby for comparison
- **Analysis**: Total Hg content analyzed using DMA-80 direct mercury analyzer
- **Results**:

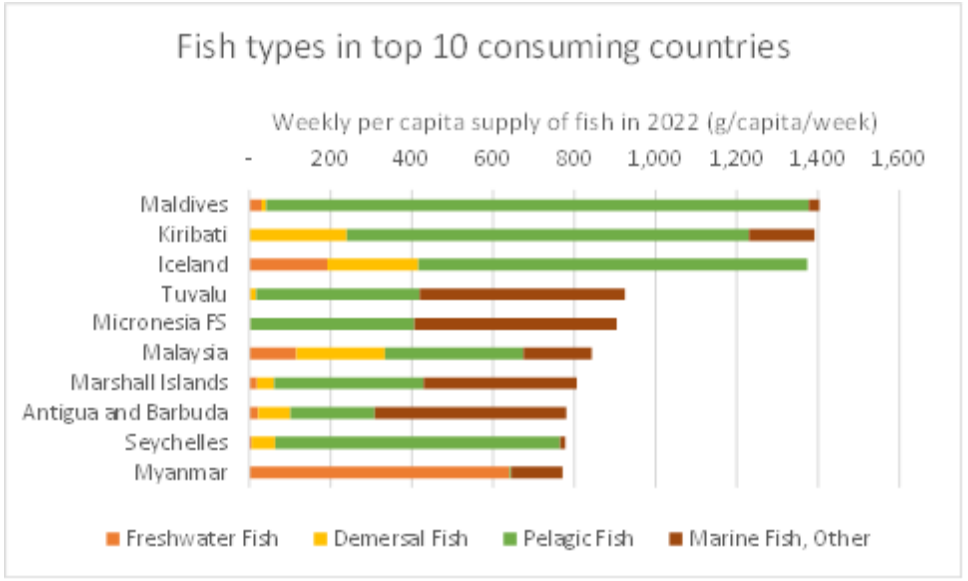
  - Mean Hg levels: 0.206 mg/Kg (WW) and 0.133 mg/Kg (WW) for reclaimed and untouched areas respectively

  - Samples near Thilafushi had considerable differences (0.235 mg/Kg) in mercury level compared with samples taken from the reef near Farukolhufushi (0.178 mg/Kg)

  - Humpback red snappers from both areas were determined to be safe for consumption under the European Union (EU) maximum permitted level (1.0 mg/Kg (WW)), given that the recommended human consumption frequency is limited to three times per week with portion size not exceeding 113 grams for a person of average weight.

Fish Consumption in Maldives

- Fish is the primary exposure route for methylmercury worldwide
- Maldives is the highest fish consuming country
- Fish consumption contributes around 71% of the animal-source protein intake of the population's diet – the highest in the world (Bennett et al. 2018)
- Fish type consumed here is predominantly pelagic species (e.g., tuna)



UN Food and Agriculture Organization (2022)

Health Impacts of Mercury

- Exposure to methylmercury can have toxic effects on the nervous, digestive, and immune systems, and on the kidneys and liver
- Fetuses and infants are the highest risk group for adverse health effects in the form of developmental and cognitive impairments, and delays in early childhood
- No clear conclusion as to the lower limit concentrations of methylmercury that causes adverse effects to the fetus
- Methylmercury gets transferred to the fetus through the placenta: monitoring and managing mercury exposure to pregnant or breastfeeding women and women in childbearing age are particularly important
- Mercury through fish consumption: must consider the value of health benefits from fish versus the adverse effects from mercury

Hair Study

Hair Mercury Levels in the Maldives: Assessing Exposure in a High Fish Dependent Population

- The first human biomonitoring survey in Maldives for Mercury – high risk of exposure in Maldives as it is the highest fish consuming country
- Survey is funded by the UNEP Mercury Project and executed by the Ministry of Climate Change, Environment and Energy of Maldives
- Survey was approved by Maldives National Health Research Council
- Consent forms used to get subject's informed consent to donate hair
- Questionnaire was used to assess fish consumption habits, awareness levels, etc
- Hair samples were collected in 2 phases:
  1. Phase 1: from all seven districts of Maldives, equally distributed by age, gender
  2. Phase 2: from the central region, only focusing on childbearing age women
- Samples were analysed by the Asian Institute of Technology, Thailand via Cold Vapor Atomic Absorption Spectrometry

Hair Study – Timeline/Steps

1. Study plan proposed to UNEP mercury project - 2022
2. Approved by UNEP (for 100 samples)
3. Training workshop held for sample collectors from regional hospitals
4. Proposal submitted to National Health Research Council
5. Proposal approved by Health Research Council
6. Sample collector briefing
7. Sample collection (101 samples)
8. Samples sent to Asian Institute of Technology (AIT) for chemical analysis
9. Results of preliminary study assessed
10. Met with UNEP mercury project to discuss results, proposed phase 2 (further 100 samples approved)
11. Phase 2 sample collectors briefing (targeting childbearing age women)
12. Sample collection (58 samples collected)
13. Samples sent to AIT for chemical analysis
14. Results of both phases combined and drafted the report
15. Paper review process (UNEP mercury project and NIMD)
16. Manuscript produced with further statistical analysis for submission to a journal
17. Report and manuscript finalised, ready for publication - 2025

Hair Sample Collection – Phase 1

- Stratified random sampling approach used
- 100 samples collected in phase 1 (preliminary study): 100 samples (25% of effective sample size of a full-scale study, an underpower probability of 35% or in other words 65% power). This is appropriate for a preliminary study as according to Tseng and Sim's (2021) suggested rule of thumb, preliminary studies should have a power of at least 60%.
- Exclusion criteria: subjects who have not lived in the region for 3 consecutive years, subjects with dyed/bleached/permed hair, vegetarians, and subjects who are smokers, cosmetic skin whitening product users
- Subjects are equally selected by gender (50:50), by age range (20 subjects each from age groups: 19 or below, 20-29, 30-39, 40-49, and 50 or above)
- Challenge encountered while sampling: cultural/religious taboos against giving hair, prevalence in smoking, prevalance in treated hair= delays in sample collection

Age Group	Age	Gender		Total
		Male	Female	
1	19 or below	10	10	20
2	20-29	10	10	20
3	30-39	10	10	20
4	40-49	10	10	20
5	50 or above	10	10	20
		Total:		100

Zone #	Region	Male	Female	Total Sample
1	North Central Province	20	20	40
2	Upper North Province	5	5	10
3	North Province	5	5	10
4	Central Province	5	5	10
5	South Central	5	5	10
6	Upper South Province	5	5	10
7	South Province	5	5	10
	Total:			100

Hair Sample Collection – Phase 2

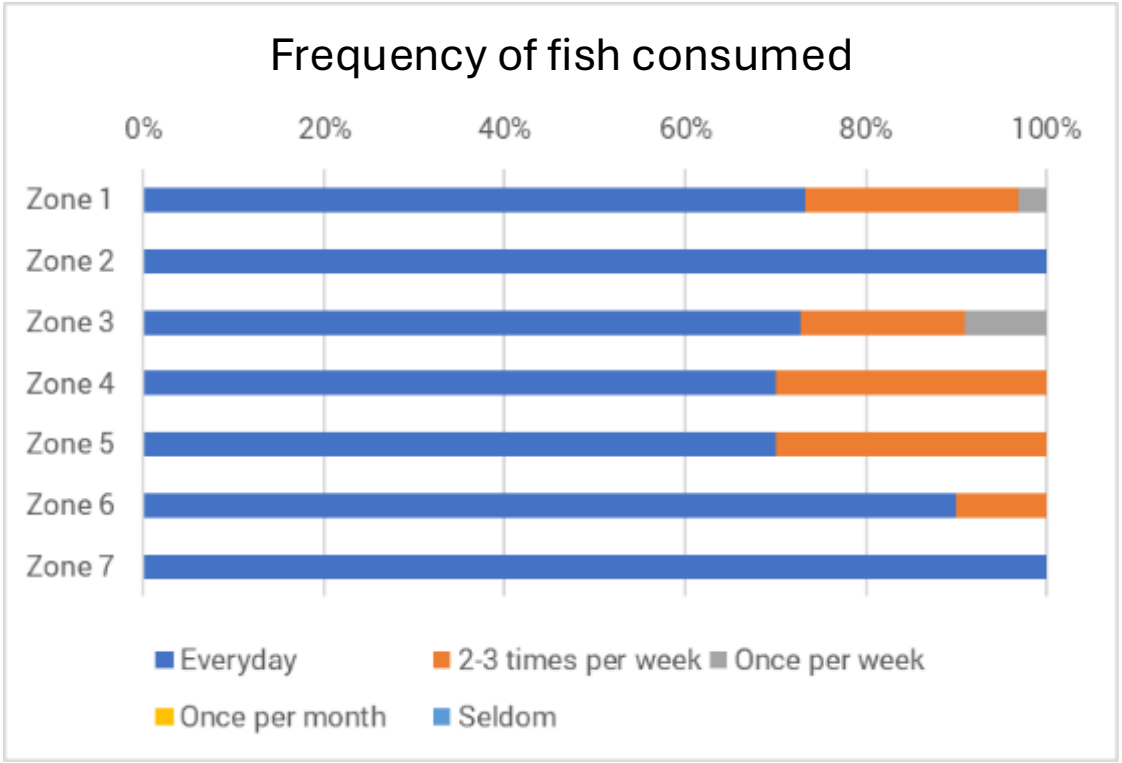
- For phase 2, only women in childbearing age from the central region were assessed
- Rationale:
  - Central region chosen for population density and accessibility for collection
  - Women in childbearing age chosen as the focus group as
- Exclusion criteria: subjects who have not lived in the region for 3 consecutive years, subjects with dyed/bleached/permed hair, vegetarians, subjects who are smokers, cosmetic skin whitening product users, pregnant/breastfeeding women
- Subjects were selected from the age range 18 to 39 (childbearing age)
- Challenge encountered while sampling: cultural/religious taboos against giving hair, prevalence in smoking, prevalance in treated hair = delays in sample collection

Total samples collected in both phases:

Zone	No. Of Samples	Province	Atolls
1	Phase 1: 40 Phase 2: 58	North Central Province	Alif Alif, Alif Dhaal, Kaafu and Vaavu
2	Phase 1: 10	Upper North Province	Haa Alif, Haa Dhaalu and Shaviyani
3	Phase 1: 11	North Province	Baa, Lhaviyani, Noonu and Raa
4	Phase 1: 10	Central Province	Dhaalu, Faafu and Meemu
5	Phase 1: 10	South Central	Thaa and Laamu
6	Phase 1: 10	Upper South Province	Gaafu Alif and Gaafu Dhaalu
7	Phase 1: 10	South Province	Gnaviyani and Seenu

Questionnaire Results – Fish Consumption

- Vast majority reported eating fish everyday
- Amount consumed per meal is moderate in most cases
- Significant preference for medium/small size tuna (e.g. frigate, skipjack, little tunny) followed by canned fish (usually has skipjack/yellowfin tuna) followed by dried/smoked fish.



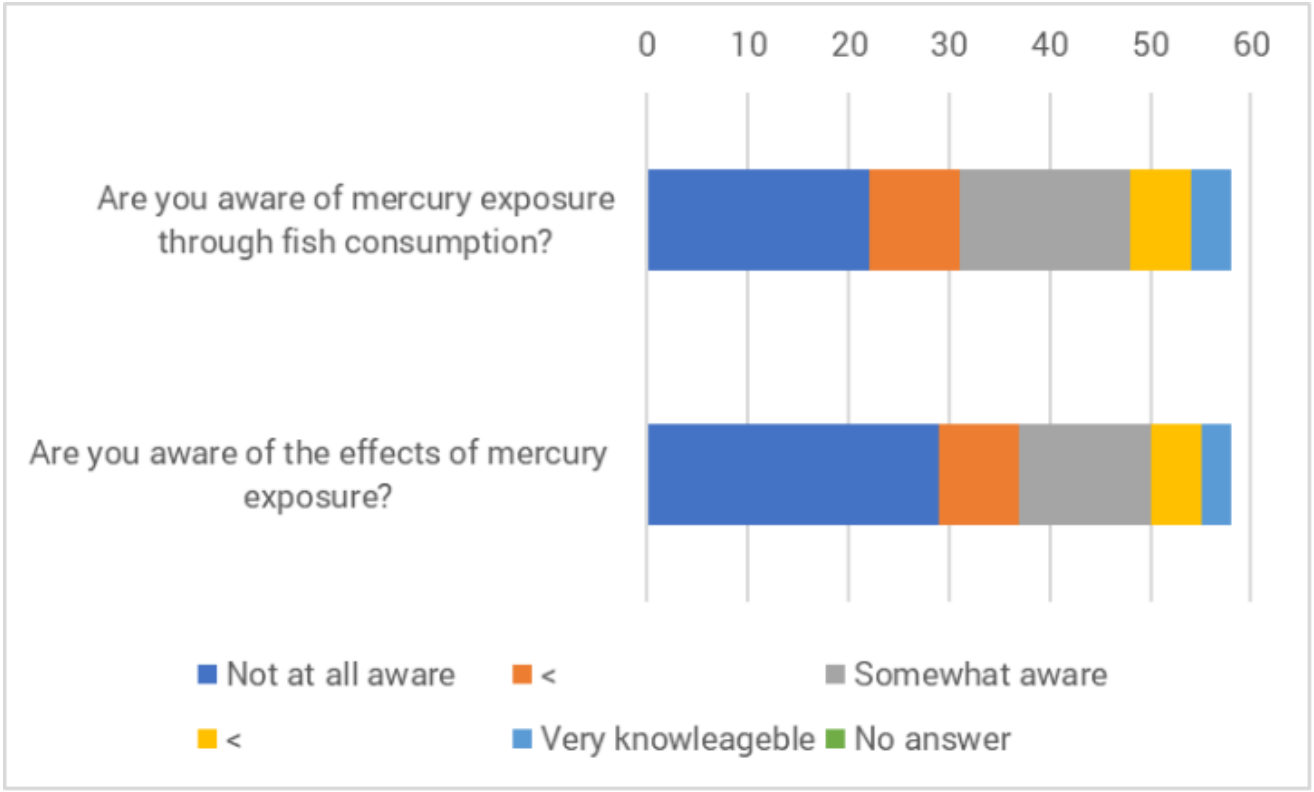
Questionnaire Results - Awareness

- Approximately a third of the subjects were not at all aware of mercury exposure through fish
- Almost half of the subjects were not at all aware of the effects of mercury exposure

Subjects who were previously pregnant:

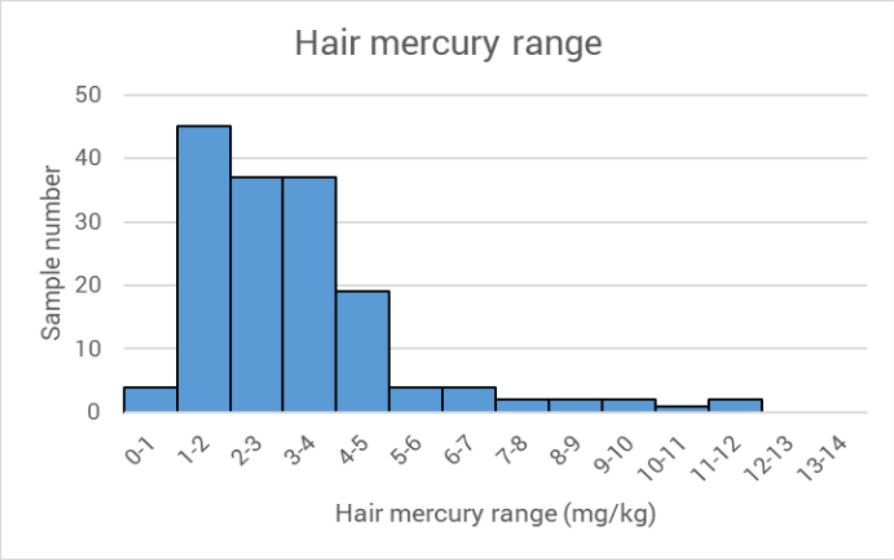
- All except two subjects reported that they were not advised by their physicians to alter their fish consumption habits during pregnancy
- All but one subject stated they did not change their fish consumption habits during pregnancy

Awareness levels assessed in phase 2



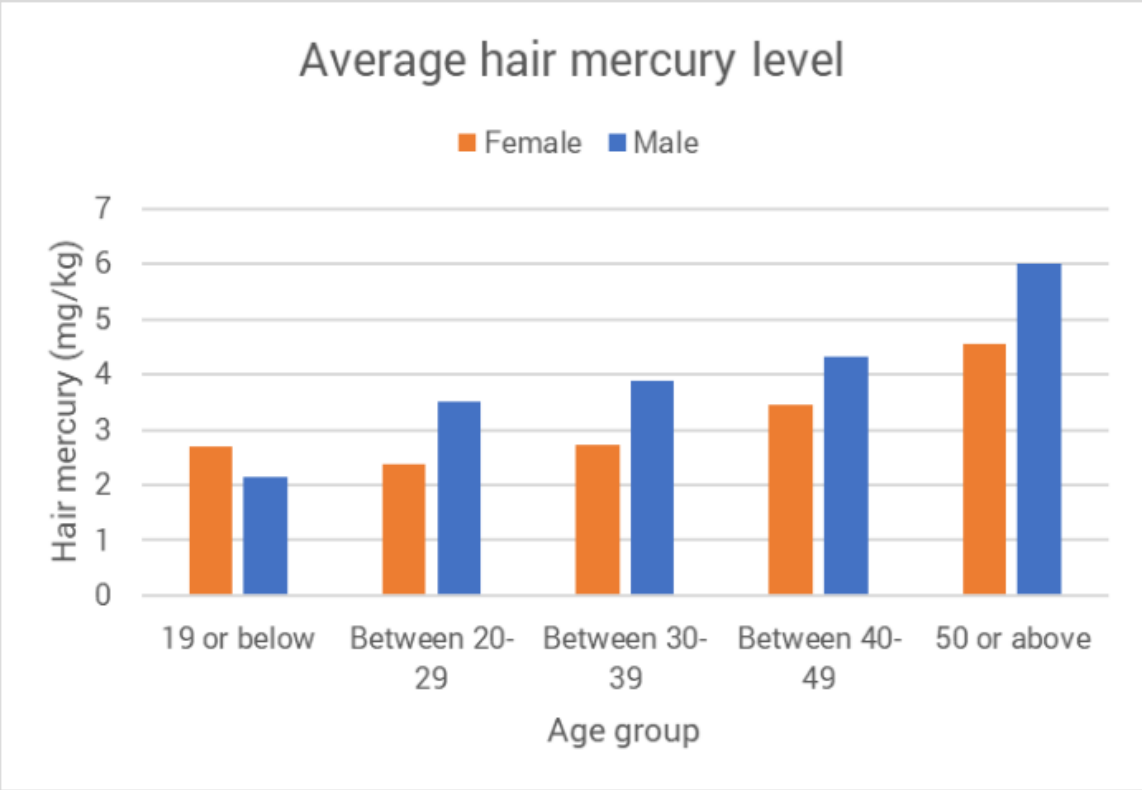
Hair Mercury Levels - Summary

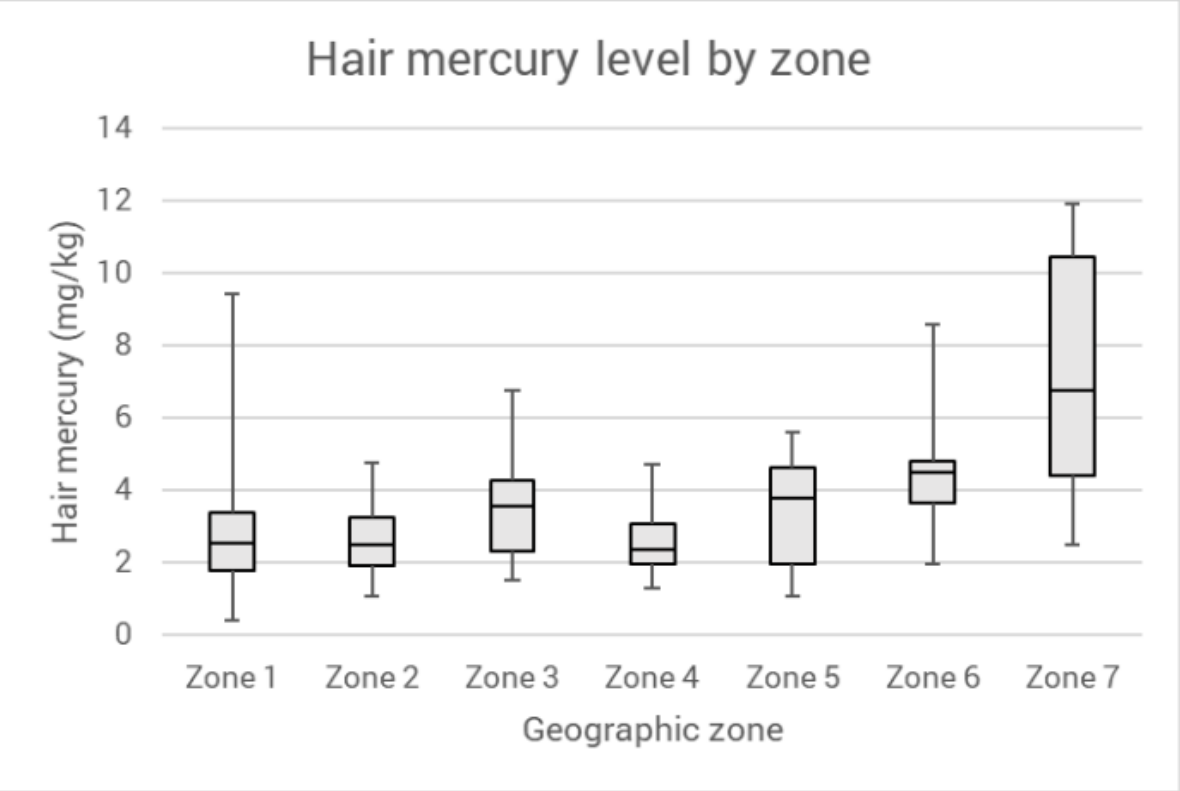
Parameter	All	Other adults (>=18)	Childbearing age women	Children (<=17)
Sample count	159	66	80	13
Average	3.22 mg/kg	4.15 mg/kg	2.66 mg/kg	1.99 mg/kg
Geometric mean	2.74 mg/kg	3.67 mg/kg	2.30 mg/kg	1.85 mg/kg
Standard deviation	2.01 mg/kg	2.22 mg/kg	1.63 mg/kg	0.85 mg/kg
Maximum	11.9 mg/kg	11.9 mg/kg	11.0 mg/kg	3.73 mg/kg



- In Phase 1: average hair mercury concentration was 3.69 mg/kg, with a maximum value of 11.9 mg/kg
- Among women of childbearing age, average mercury level was 2.66 mg/kg, with a maximum of 11.0 mg/kg
- Overall average was 3.22 mg/kg with a maximum of 11.9 mg/kg
- Highest frequency was seen in the 1-2 mg/kg range

Hair Mercury Levels by Demographic Factors

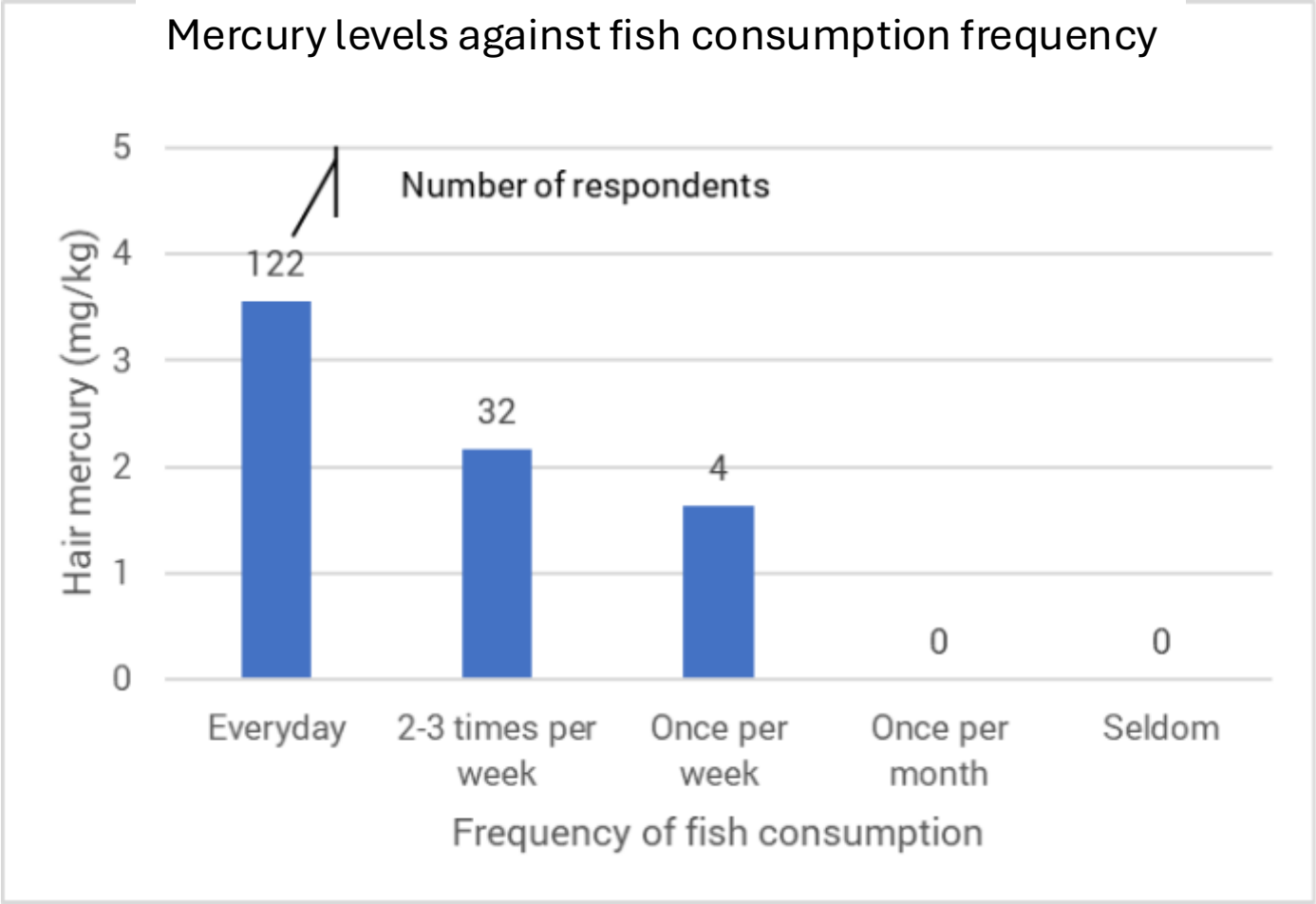




- Patterns are typical to similar studies: mercury levels increasing with age and higher mercury levels in males
- Males have higher levels likely due to higher consumption of fish
- The differences in zones need to be further investigated, phase 1 of the study does not have enough samples for accurate quantitative comparisons between zones

Hair Mercury Levels vs Fish Consumption

- There is a clear increasing trend in mercury levels with the increased frequency of fish consumed
- No significant differences were observed for the amount of fish consumed per meal (difficult for subjects to estimate weight of fish retroactively)



Reference Values for Hair Mercury

Reference	Description	Target population	Hair mercury reference value
WHO/JECFA (2007)	NOAEL for maternal hair: neurodevelopmental effects in the fetus.	Fetus*	14 mg/kg
	Corresponds to the PTWI (1.6 µg/kg/week) for women of childbearing age to protect fetus development.	Fetus*	2.2 mg/kg
	Intakes of up to about two times higher than the existing PTWI (corresponding to 4.4 mg/kg) would not pose any risk of neurotoxicity in adults.	Adults	4.4 mg/kg
	Infants and children aged up to about 17 years might be more sensitive than adults (no firm conclusion).	Infants & children	Inconclusive between 2.2 and 4.4 mg/kg
Japan (2005)	NOAEL for maternal hair: on the fetus development.	Fetus*	11 mg/kg
	TWI for fetus based on the methylmercury intake by pregnant women.	Fetus*	2.8 mg/kg
USEPA (2001)	Corresponds to benchmark dose lower limit (the lower 95 % confidence limit) in maternal hair for different neuropsychological effects in the offspring at 7 years of age.	Fetus*	10~14 mg/kg
	Corresponds to an intake of 0.1 µg/kg/day, without an appreciable risk of negative effects during a lifetime, typically used for low fish consuming populations.	Fetus*	1.1 mg/kg

*Fetus: assessed by maternal hair mercury

Hair Mercury Levels Against WHO Ref

Reference level (mg/kg)	Adults excl. CBA	Women in childbearing age	Children	Total
Below 2.2	11% (7)	46 % (37)	77 % (10)	Below reference 59 % (94)
Between 2.2 – 4.4	60 % (40)	43 % (34)	23 % (3)	Range for children 2 % (3)
Between 4.4 - 14	29 % (19)	11 % (9)	0 % (0)	Above reference 39 % (62)
Above 14	0 % (0)	0% (0)	0 % (0)	Above NOAEL 0 % (0)
Total:	100% (66)	100% (80)	100% (13)	100 % (159)

- Overall, 39% of samples exceeded the reference values derived from Provisional Tolerable Weekly Intake proposed by the WHO (excluding children over 2.2 mg/kg)
- 54% of women in childbearing age had mercury levels above 2.2 mg/kg, indicating potential risks to fetal development if the levels are kept up during a pregnancy

Conclusion

- Maldives is the highest fish consuming country in the world – fish is the main source of methylmercury in humans worldwide - risk for methylmercury exposure is high in Maldives
- Mercury levels in the general population is moderately high, similar to other coastal/high fish consuming countries – no immediate risk to the general population
- Mercury levels are higher than guideline values for women in childbearing age – risk to fetus if levels are maintained into a pregnancy
- Lack of awareness about mercury and exposure routes
- There are no prenatal/maternal dietary advisories regarding fish consumption
- Need to conduct studies on mercury levels in locally consumed fish to develop context specific dietary advisories, especially targeting women of childbearing age/pregnant women
- Dietary advisories should simultaneously promote the health benefits of fish while recommending safe consumption levels, especially for vulnerable groups

Thank You

Citation for this presentation

Detailed report:

Paper: