

# Health Determinants of Methylmercury Exposure in Coastal Pakistani Women: Fish Consumption and Environmental Influences

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## ABSTRACT

**Objective:** To estimate MeHg levels in the scalp hair of women from a coastal community in Sindh province and examine the relationship between fish consumption and other risk factors.

**Methodology:** A cross-sectional study was conducted among 100 women aged 15-49 years in Rehri Goth, Sindh. Detailed dietary histories were obtained through interviews. Scalp hair samples were analyzed for total mercury using Cold Vapor Atomic Absorption Spectrophotometry.

**Results:** The median hair MeHg level was 7.15 µg/g, exceeding international guidelines. Higher levels were associated with fish from polluted waters (3.5 µg/g), skin whitening product use (6.5 µg/g), and traditional medicine intake (9.0 µg/g). A weak positive correlation was found between MeHg and age. Fish consumption averaged 4 times/week.

**Conclusion:** Women in coastal Sindh have high MeHg exposure from frequent fish intake, likely exacerbated by industrial pollution. Risk mitigation is needed to protect vulnerable populations, especially during critical windows of neurodevelopment.

**Keywords:** Mercury Pollution, Methylmercury Exposure, Fish Consumption, Coastal Communities, Pakistan

### Authors' Contribution:

<sup>1,2</sup>Conception; Literature research; manuscript design and drafting; <sup>2</sup> Critical analysis and manuscript review; <sup>1</sup> Data analysis; Manuscript Editing.

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## Introduction

Mercury (Hg) is a naturally occurring metallic element found in the earth's crust, released into the environment through both natural and anthropogenic sources.<sup>1</sup> The sources of mercury include natural geological processes, human activities, and re-emissions of previously deposited mercury in soil and oceans. Anthropogenic sources,

such as combustion of fossil fuels, industrial processes, cement production, and waste incineration, contribute significantly to environmental mercury levels.<sup>2</sup> Presently, mercury levels in the atmosphere are several times higher than pre-industrialization estimates.<sup>3</sup>

Mercury has the ability to bio-transform into methylmercury (MeHg) through bacterial processes in aquatic environments.<sup>4</sup> MeHg is highly toxic and can

accumulate and bio-concentrate in the aquatic food chain, primarily through fish consumption. Numerous studies have established a link between fish consumption and mercury exposure.<sup>5,6</sup> This is a significant public health concern as methyl mercury can pass through the placental barrier and affect the developing fetus, leading to neurotoxic and developmental abnormalities.<sup>7</sup>

Several large epidemiology studies have reported an inverse dose-response relationship between children's neurobehavioral performance and maternal consumption of methylmercury-contaminated seafood during pregnancy.<sup>8,9</sup> A subsequent meta-analysis of these studies found a dose-response relationship between methylmercury and IQ, highlighting the long-term cognitive impact of mercury exposure.<sup>10</sup> These adverse effects pose a significant economic burden, estimated to range from \$7 to \$43.8 billion per year in the United States<sup>(11)</sup>. Hair samples have been widely used as they correlate well with dietary methylmercury intake.

MeHg is absorbed into the bloodstream and eventually incorporated into hair as it grows. Therefore, analyzing hair samples can provide a reliable indication of an individual's MeHg exposure over time and offer a simple and non-invasive collection method. Pakistan, as a developing country with high energy needs, has several operational thermal and hydropower plants. However, the collective impact of these emissions has not been adequately considered, and there is a lack of ambient air quality standards and regional air quality assessments. Coastal areas, such as Karachi, face additional challenges due to the discharge of untreated industrial and municipal waste into the sea.

Consequently, fish caught in these coastal waters may contain elevated levels of mercury, posing a potential risk to the population. No exposure assessment has been conducted to measure mercury levels in the bodies of individuals in this community. Therefore, we propose to conduct a

preliminary study to estimate the proportion of women consuming fish and determine the relationship between fish consumption and mercury levels in their scalp hair.

## Methodology

We conducted a cross-sectional study to assess methylmercury (MeHg) exposure from fish consumption among women of childbearing age in Rehri Goth, Pakistan. Rehri Goth is a coastal fishing community near Karachi characterized by reliance on fishing and potential exposures to industrial pollutants and MeHg. This setting was chosen due to unique exposure risks, particularly from locally caught fish that are regularly consumed.

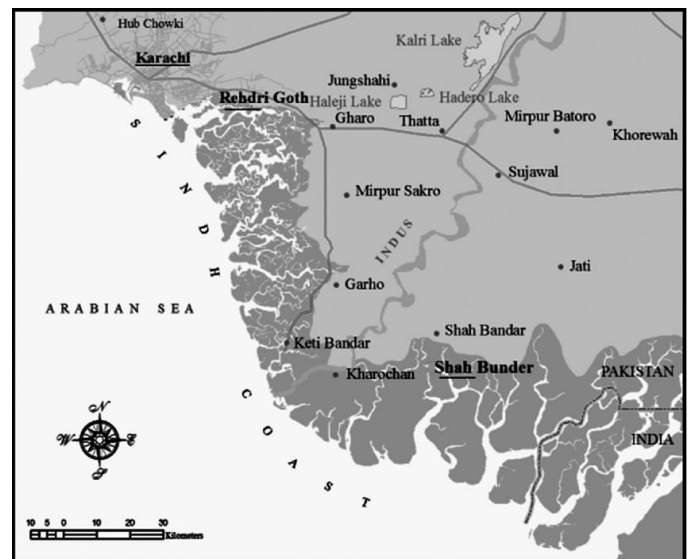


Fig. 1. Site of study

The study population included women aged 15-49 years residing in Rehri Goth for at least one year who consume fish at least four times per week. The rationale behind selecting women aged 15 to 49 years is their potential role as child bearers and the associated risks to foetal development. Methylmercury is known to have neurotoxic effects, and exposure during pregnancy can have detrimental effects on the developing fetus (Farzan, 2021 #30) Exclusion criteria were severe illness, mental incapacitation, or any condition preventing communication.

Based on a hypothesized correlation between scalp hair MeHg and fish intake, we calculated a target sample size of approximately 100 subjects to ensure 95% confidence and 80% statistical power. Participants were recruited through household visits using purposive sampling aimed at enrolling childbearing-age women. Written informed consent was obtained before interviews and hair sample collection using a standardized, non-invasive method involving cutting a sample of hair close to the scalp. This provides a long-term measure of mercury exposure reflecting levels in the blood. Hair samples were sent to the laboratory where they underwent a cleaning process involving washing twice with deionized water and acetone to remove external contamination. The samples were then dried, weighed, and digested using nitric acid at high temperatures in a microwave digestion system. Digested samples were then analyzed for total and methyl mercury using cold vapour atomic absorption spectrophotometry.

Ethical approval was granted by the Ethical Review Committee of Aga Khan University, Karachi, to ensure adherence to ethical standards and participant protection. Data collection involved sociodemographic and dietary questionnaires administered by local research assistants trained in survey techniques. Statistical analyses summarized sociodemographic characteristics and described potential exposure factors.

## Results

A total of 100 women of reproductive age were recruited with a mean age of 25 years. The sociodemographic characteristics are summarized in Table 1. The majority were married (64%) and had primary education or below (76%). The median total household income was 15,000 Pakistani rupees. The median concentration of methylmercury in scalp hair was 7.15 µg/g, with a cut-off of 0.3 µg/g. The average self-reported weekly fish consumption from the food frequency questionnaire was approximately 4 times.

As shown in Table 2, higher median methyl mercury levels were found in women who reported using skin whitening creams/soaps (6.5 µg/g), eating fish caught from waters near industries (3.8 µg/g), and using traditional or herbal medicines in the last six months (9.0 µg/g).

**Table 1: Socio-demographic characteristics of the study population**

Variable	Characteristic [n (%)]
Age (mean) (S.D)	25 years (7.23)
Marital status	
- Married	49 (64)
- Unmarried	27 (36)
Education	
- ≤ primary	58 (76)
- Secondary	18 (24)
Total household income (median)	15000 (Pak rupee)
Average weekly fish consumption	~ 4times/weeks
Use skin-whitening soap	
- yes	35 (46)
- no	41 (54)
Methyl mercury in hair samples (median)	7.15 µg/g, [cut-off 0.3 µg/g]

**Table 2: Median methyl mercury levels in scalp hair (ug/g) [Cut-off: 0.3 µg/g]**

Variable	Median	Minimum	Maximum
Use of skin whitening soaps/creams	6.5	1.0	23.0
Fish caught from areas near industries	3.8	1.0	31.8
Use of traditional or herbal medicine/s in the last six months	9.0	1.1	20.0

There was a weak but significant correlation between hair mercury levels and age ( $p=0.470$ ,  $p=0.002$ ). However, no correlations were observed between hair mercury and education, marital status, or income Table 3.

## Discussion

In this study, we aimed to investigate the levels of methyl mercury (MeHg) in the scalp hair of 100 women of reproductive age. Our study population consisted of women with a mean age of 25 years, predominantly married and with limited education (less than primary schooling). Their average

household income was 15,000 PKR, reflecting a modest socioeconomic background. Notably, the median concentration of MeHg in scalp hair was found to be 7.15 µg/g, substantially higher than the suggested cut-off of 0.3 µg/g<sup>(12)</sup>. This result is concerning, as it indicates a prevalent exposure of MeHg among these women.

**Table 3: Correlation Matrix of Demographic and Health Factors**

Variables	Age	Hair Mercury	Frequency/amount of fish consumed	Education	Marital status	Total household income
Age	1.000	.470*	.059	.388*	.691**	.355
Hair mercury	.470*	1.000	.011	-.031	.019	.026
Frequency/amount of fish consumed	.059	.011	1.000	.219	-.041	.165
Education	.388*	-.031	.219	1.000	.036	.024
Marital status	.691**	.019	-.041	.036	1.000	.030
total household income	.355	.026	.165	.024	.030	1.000

**Correlation is significant at the 0.05 level (2-tailed)**  
**Correlation is significant at the 0.01 level (2-tailed)**

Our study found that the frequency/amount of fish consumed was not associated with an increased concentration of mercury in scalp hair. This finding is in contrast with the studies conducted in different countries including Pakistan.<sup>13-15</sup> One of the reasons for this could be that in cities, people mainly consume large fish for eating. The lack of association could be due to the consumption of small fish, which tend to have lower levels of mercury. Mercury tends to accumulate as fish grows in size or in large fish, and also depends on fish species such as Mackerel, Shark, and Swordfish, which tend to have high levels of methylmercury. Interestingly, we observed a weak but significant positive correlation between age and MeHg levels in hair ( $r = 0.6, p = 0.002$ ). This suggests that MeHg accumulation in hair may increase with age, possibly due to prolonged exposure over time {Kippler, 2021 #56}. However, no significant correlations were found between MeHg levels and education, marital status, or income, see Table III. This underscores the importance of age as a potential determinant of MeHg exposure in this

population. While some studies are congruent with our finding {Kippler, 2021 #56} a study conducted recently found no significant association between age and hair mercury concentration {Cegolon, 2023 #57}. Factors such as lifestyle, diet, geographical location, and occupational exposure can also impact MeHg levels in individuals. Our study also investigated specific lifestyle factors that might contribute to elevated MeHg levels. Notably, women who reported using skin whitening creams

or soaps had higher MeHg concentrations (6.5 µg/g), suggesting a potential link between the use of these products and MeHg exposure. Our findings are consistent with the studies conducted in Pakistan<sup>16-18</sup> and other countries.<sup>19,20</sup> Additionally, those who consumed fish caught from waters near industrial areas had an elevated MeHg level of 3.5 µg/g, highlighting the importance of monitoring MeHg levels in seafood from such regions. This finding is consistent with the results of a study that found individuals who consume fish from these areas may have elevated levels of MeHg in their scalp hair.<sup>21</sup> This could be due to the reason that high levels of mercury are found in the coastal waters, particularly the waters near industrial areas of Karachi.<sup>22</sup> Furthermore, the use of traditional or herbal medicines in the last six months was associated with the highest MeHg levels (9.0 µg/g). This result is in line with the studies conducted in other countries.<sup>23,24</sup> This finding raises concerns about the potential sources of MeHg contamination in these products and the need for further investigation and regulation in this regard.

Based on our findings, it is crucial to emphasize the importance of safe product use and the monitoring of MeHg levels in commonly consumed foods, especially fish sourced from potentially contaminated waters. Additionally, further research is warranted to identify the specific sources of MeHg in skin whitening products, traditional medicines, and fish from industry. This study's strength lies in its examination of multiple exposure factors to MeHg, offering a comprehensive insight into its potential health impacts. However, it is limited by its reliance on self-reported data, which may introduce bias, and the absence of dietary quantification in certain analyses. To overcome these limitations, future research should consider utilizing biomarkers and validated dietary assessment tools. Such approaches would enhance the precision of exposure assessments and facilitate a more accurate correlation between MeHg exposure sources and health outcomes, contributing to a deeper understanding of MeHg's effects on human health

## Conclusion

The conclusion of our study underscores the concerning levels of mercury found in the scalp hair of women, which alarmingly, minimally correlate with fish consumption. Instead, factors such as the use of skin-whitening products and soaps, traditional medicine practices, and sourcing fish from areas near industrial activities emerge as significant contributors. This situation underscores the broader issue of pollution's impact on mercury levels. Consequently, it is imperative for governmental bodies to enforce regulations against the use of mercury in cosmetics and skin-whitening products. Moreover, the Environmental Protection Agency (EPA) must strengthen and enforce regulations on pollutant emissions into water bodies and the atmosphere. Such steps are critical to safeguard public health and reduce the risks associated with elevated mercury exposure in women.

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