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Mercury Exposure in the Scalp Hair of Malahing Residents, Bontang, East Kalimantan

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Abstract

Research on mercury exposure in the scalp hair of Malahing Village residents has been done. They consume fish in their daily lives so they are potentially exposed to mercury. The total mercury content in their scalp hair was measured by Thermal Decomposition Gold Amalgamation Atomic Absorption Spectroscopy Method. The analysis result showed that the mercury content in their scalp hair was between 0.34-2.73 ppm. Mercury levels in the scalp hair of female and male samples are not significantly different. There is a tendency for mercury levels to increase with age.

Key words: mercury, scalp hair, biomarker, fish

Introduction

Mercury is found in the layers of the earth's crust and can be released into the environment around us, both due to natural activities such as rock weathering, mountain eruptions and water cycles, and by human activities such as mining, coal-fired power plants, industrial processes, the use of products containing mercury and dental fillings with amalgam (FAO/WHO, 2007).

Mercury exists in several oxidative states, as an inorganic salt, and as an organic complex. The oxidative state consists of the element mercury (Hg^0), mercury (Hg^{+1}), or mercury (Hg^{+2}). Mercury in any form is toxic (Broussard *et al.*, 2002).

Mercury in any form will bind with sulfhydryl (-SH) groups in thiols or proteins. Sulfur is present in the amino acids, such as cysteine, methionine and cysteine-derivative taurine. Because the receptors in/on the cell membranes are

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all built from proteins, those receptors are susceptible to attack by various forms of mercury. When mercury binds to one of the amino acid residues in the receptor protein, it reduces the availability of protein molecule's range for normal metabolic function. The strong affinity of the sulfhydryl (-SH) group for mercury has often been considered to be the mechanism of toxic action of mercury and its compounds. Methylmercury can form small molecular weight thiol complexes that have high mobility in the body that are readily transported across membranes of cells (ATSDR, 2013).

The main targets for the toxicity of mercury and its compounds are the nervous system, kidneys, and cardiovascular system. Other systems may also be affected, such as the respiratory, immune, hematological, gastrointestinal and reproductive systems. Developing organ systems such as the fetal nervous system are most sensitive to the mercury toxic effects (UNEP, 2010).

Methylmercury biomagnifies in food webs, especially in the aquatic food webs. The human body is exposed to methylmercury compounds most likely through fish consumption. The fish consumption pathway is more likely happen than other pathways (USEPA, 1997). The level of methylmercury exposure depends not only on the mercury content in fish, but also the amount and frequency of consumption (UNEP/WHO, 2008).

The total mercury content in hair is about 250 to 300 times higher than the mercury content in blood when hair is formed. The mercury content in hair is usually 1-2 ppm, but people who eat more fish every day may have more than 10 ppm in their hair. The USEPA reference dose (RfD) corresponds to about 1 ppm mercury in the hair of people who rarely consume fish. Methylmercury content in fish consumers' hair is around 80% of the total mercury (UNEP/WHO, 2008).

Scalp hair has been widely used as a biomarker of the exposure of mercury to human body for the following reasons: (1) it is easy to be collected in a non-invasive way (2) it does not need special equipment or tools for storage or transport (3) it can describe the history of mercury exposure. Mercury can penetrate into the hair follicle during its growth process and become stable giving a history of exposure; therefore, the closest hair to the scalp reflects the most recent methylmercury exposure. The hair can be a good long-term biomarker of exposure to methylmercury, since once the methylmercury from the bloodstream is incorporated into the hair it will not return to the bloodstream again, thus it provides a good long-term marker of exposure to methyl mercury (Vieira *et al*., 2014).

Observation results show the Malahing residents consume fish in their daily lives. People who consume a large amount of fish is potential to be exposed to mercury which harms the health of the body (Vieira *et al*., 2014). The analysis results showed the presence of mercury in fish consumed by Malahing residents ranging from 0.002 ppm to 0.042 ppm, so they are potentially exposed to mercury. A research needs to be done to ensure the mercury level exposure in the Malahing residents is still within safe limit. The research data will be very useful for related parties or institutions in carrying out mercury risk management programs.

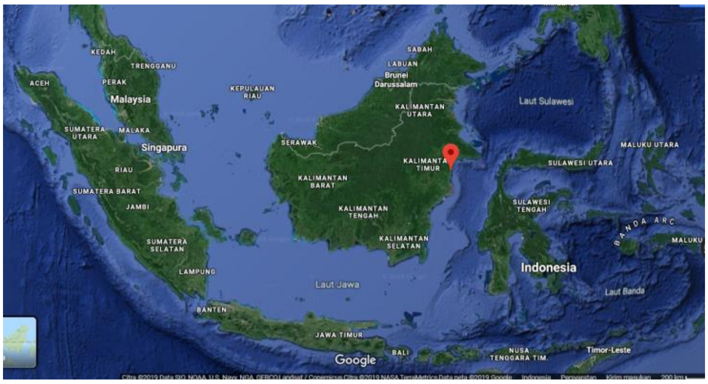

Figure 1. Geographical Location of Malahing Village

Malahing Village is one of the fishing villages located above shallow seas, part of the Makassar Strait Sea, at the coordinates of 0°06'52.9 "N 117°31'47.4" E. Malahing Village is administratively included in South Bontang Sub-district, Bontang Distric, East Kalimantan Province, Indonesia.

Materials and Methods

Sampling and preparation

Scalp hair sampling was performed on 36 people representing the total number of Malahing Village residents which around 120 people. The samples consist of 18 men and 18 women. Participants were selected based on the criteria of (1) their age (8-57 years), (2) willingness to participate, and (3) having sufficient hair to provide a sample for analysis.

The sampling procedure is as follows: first, disinfection the scissors and clips by placing them in 70% isopropyl alcohol in a sealed disinfection container. Then, isolation a bundle of approximately 100 strands of hair in the occipital region of the scalp and twist together. The hair is cut as close as possible to the scalp. The scalp hair sample is kept in a plastic bag.

Mercury analysis

Analysis of the total mercury content in hair is carried out using the mercury analyzer Nippon Instruments Corporation SP-3D. The analyzer was chosen because the preparation process is quite simple.

Summary of the method is as the following description. Decomposition of the sample is carried out in the catalytic part of the furnace with oxygen flow. Nitrogen oxides, sulfur oxides and halogens after the oxidation process will be trapped. Other decomposition products continue towards amalgamators which will trap mercury selectively. Mercury vapors in the amalgamator are released by heating rapidly after the remaining gas or decomposition products are removed. Mercury vapor will be carried by oxygen flow through absorbance cells. The cell will be passed by a light atomic absorption spectrophotometer with a single wavelength. Absorbance was measured at 253.7 nm to determine the concentration of mercury in the sample (USEPA, 1998).

Data evaluation

The mercury level exposures in the hair of the Malahing residents are compared to safe limits according to the threshold set by WHO, namely (1-2) ppm and The USEPA references of dose (RfD) corresponds to approximately 1 ppm. In addition, it was also carried out statistically data processing to determine whether the age factor affected the mercury level exposure in the hair and whether there is a difference in the mercury level exposure in the hair of women and men with the t-test, whereas to find out the degree of correlation is determined from the correlation coefficient.

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Results and Discussion

Mercury level exposure

The analysis result showed that the content of the mercury in the scalp hair of Malahing residents was between 0.34-2.73 ppm and the overall mean was 1.23 ppm (Fig. 2). The percentage of individuals with mercury content in the hair exceeds U.S. EPA`s references of dose (RfD) of 1 ppm is 64%. Meanwhile, the percentage of individuals with mercury content in the hair that exceeds the normal limit of the World Health Organization of 1-2 ppm is 19%.

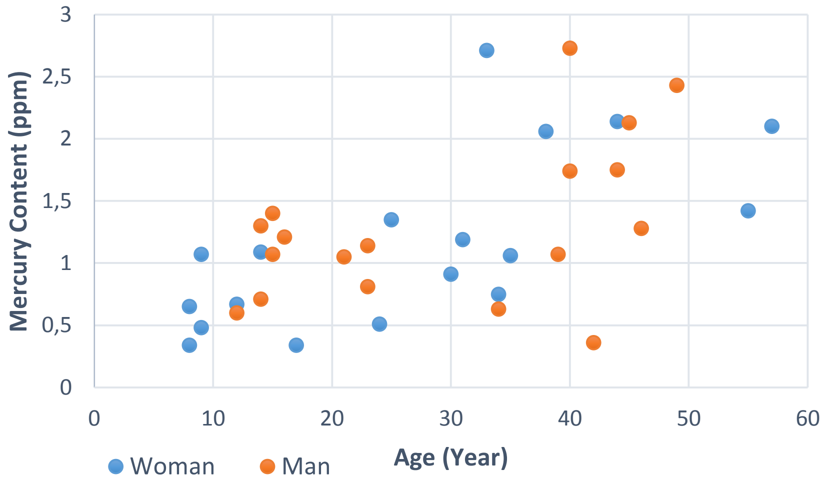

Figure 2. Data Distribution of Mercury Content in Scalp Hair

The human body is exposed to methylmercury compounds most likely through fish consumption. The fish consumption pathway is more likely to occur than other pathways (USEPA, 1997). The residents of Malahing Village, located above the shallow sea of Bontang, consume fish in their daily life. The fishes being consumed contained mercury ranging from 0.002 ppm to 0.042 ppm which results in the exposure of mercury to the community. By referring to IOMC (2008), the mercury content in hair is commonly 1-2 ppm, but people who eat more fish every day may have more than 10 ppm in their hair. The mercury content in the scalp hair of Malahing residents are still within reasonable limits.

The exposure level of methylmercury depends not only on the mercury content in fish, but also the amount and frequency of consumption (IOMC, 2008). The Malahing community needs to limit the amount and frequency of fish consumption to control the mercury level.

Correlation between age and hair mercury content

A scattered diagram showing the correlation between age and content of mercury in the scalp hair is shown in Figure 3. The content of mercury in the scalp hair of older subjects is significantly higher than in younger one. In addition, the content of mercury in the scalp hair was significantly correlated with age (A) in the following regression equation Hg = 0.0275 (A) + 0.4528 (r^2 = 0.3627, p = 0.0297). Using this regression equation, we estimate that the increase of age associated with a 1.05-times increase in content of mercury in the scalp hair.

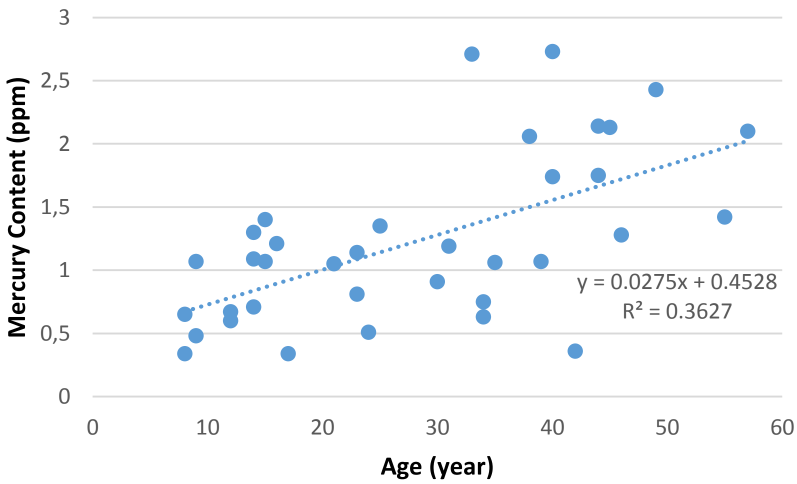

Figure 3. Correlation between Age and Hair Mercury Content
*: $p < 0.05$

After accumulating in the body in oxidized state, methylmercury can cross the boundary of tissues and cells that are immune to mercury itself. In this way methylmercury acts as a very effective storage and transportation mechanism for mercury in living organisms (Bruner, 2017).

When people are exposed to methylmercury, mercury in the blood stream moves to the follicle during the hair growth stage and is accumulated there (Hong *et al*., 2012). Autoradiography studies with tritium-labeled methylmercury demonstrated that methylmercury concentrated in hair follicles in the skin. Within hair follicles and hairs, methylmercury accumulated in regions that are rich in high-sulfur proteins (Shi *et al*., 1990).

Comparison of mercury content in women's and men's scalp hair

Each woman or man has different physiological susceptibility to the effects of exposure to toxic chemicals in relation to their reproductive cycle (UNDP, 2011). This study intended to verify whether gender has a significant effect on mercury exposure to hair. Different levels of mercury in women's and men's hair resulted from this study describes the different effect of mercury exposure to female and male subjects. The level of difference was measured by the independent sample t-test. The t-value shows whether gender has a significant effect on the exposure in which if the result of the t-value is greater than t-table then the difference is declared significant and vice versa, if the value of t is smaller than t table then the difference is declared not significant.

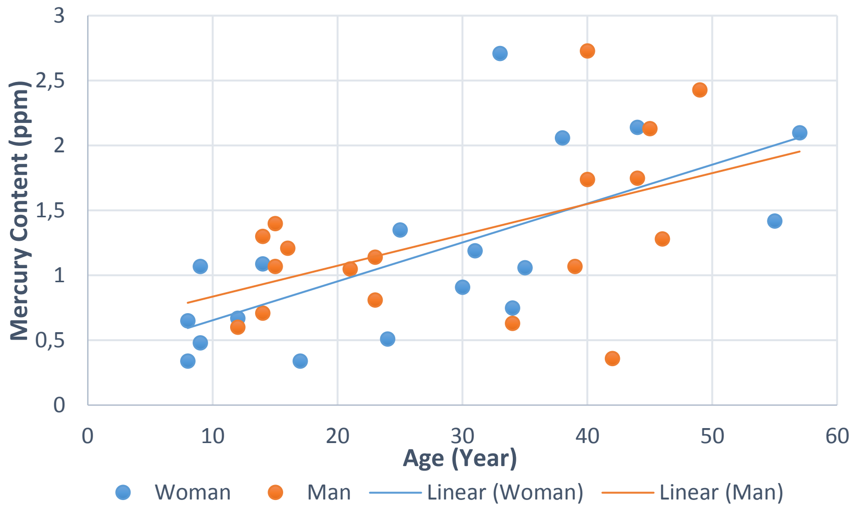

Figure 4. Comparison of Mercury Content in Women's and Men's Scalp Hair

The results of data processing showed that the t-value was 0.64116 smaller than the t-table which was 0.68156 with a confidence level of 95%. It means that the mercury content in male and female scalp hair was not significantly different or gender does not have a significant effect on the mercury exposure. This result is consistent with the previous study which stated that there was no correlation between levels of mercury in hair with gender (Kružíková *et al*., 2008).

Conclusion

The mercury content in Malahing residents scalp hair was between 0.34-2.73 ppm and the overall average was 1.23 ppm. The results showed 19% of the subjects had mercury content in their scalp hair that exceeded the World Health Organization's normal limit of 1-2 ppm. However, this number is still within reasonable limits, where according to the IOMC people who eat more fish every day may have more than 10 ppm of mercury in their hair. The mercury content in scalp hair is significantly correlated with age of which older subjects tend to have higher mercury content in their scalp hair. The mercury content in male and female scalp hair does not differ significantly, thus gender does not have a significant effect on mercury exposure.

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