



RESEARCH ARTICLE

Analysis of Determinants of Mercury Exposure on Neurological Symptoms in Small-Scale Gold Workers in Tallo District Makassar City

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| ARTICLE INFO | ABSTRACT |
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| Received: Dec 12, 2024 Accepted: Jan 1, 2025 | Mercury exposure is a toxic metal that has long-term risks to human health such as neurological symptoms. Mercury pollution has become an issue of international concern. This can happen if in gold refining using mercury and unawareness of occupational safety in the workplace. |
| Keywords Mercury Exposure Gold Workers Hair Neurological Symptoms | This study aim to determine determinants that affect neurological symptoms in small-scale gold workers in Tallo District, Makassar City |
| *Corresponding Author: iincahyani1999@gmail.com | This cross-sectional study involved 30 workers who gave informed consent and met the inclusion criteria. Data analysis was performed using chi-square and logistic regression models and data were analyzed using SPSS 25.0 |
| | Based on the outcomes of statistical analyses, it seems that working period (P=0.007), use of personal protective equipment (P=0.002), and mercury concentration (P=0.001) have an effect on neurological symptoms. Age (P=0.114), working hours in a day (P=0.273), and smoking habit (P=0.760) had no significant effect on neurological symptoms in small-scale gold workers in Tallo District, Makassar City |
| | Mercury concentration is the most dominant determinant of neurological symptoms and tends to increase with years of work and lack of personal protective equipment. |

INTRODUCTION

Mercury is a highly toxic pollutant that threatens public health and the environment. Humans are exposed to organic mercury through fish consumption, while exposure to inorganic mercury mostly occurs through breathing by inhaling mercury vapor (Abbas et al., 2017). Small-scale mining activities in the amalgamation process use mercury (Hg) as a medium to bind gold (Cheng et al., 2022). Mercury components have different characteristics for toxicity, distribution and accumulation as well as collection and resistance time in the body. Because metal mercury is highly toxic, it cannot be destroyed by organisms in the environment (Briffa et al., 2020).

In artisanal and small-scale goldsmith, Hg-based gold extraction is a common practice. As many as 37% of small-scale gold workers are the largest source of anthropogenic Hg pollution. Worldwide, an estimated 14-19 million people work in small-scale goldsmith which is the largest source of mercury emissions and releases worldwide Although Hg is toxic, amalgamation is a simple, fast and cost-effective method (Calao-Ramos et al., 2021).

Without realizing the negative impact of using mercury in goldsmith activities, namely the emergence of water, air and soil pollution and can cause health problems for workers. One of the symptoms of health problems is neurological symptoms. Mercury in the body is a dangerous substance because it causes symptoms of chronic poisoning that are permanent and cumulative in a long time. Disorders of the central and peripheral nervous systems brought on by exposure to hazardous mercury compounds are linked to neurological symptoms. According to certain research, acute neurological problems manifest as hearing loss 3 (3.8%), emotional lability 7 (9.0%), and headaches 38 (48.7%).

Insomnia 29 (37.2%), tremor 8 (10.3%), memory loss 7 (9.0%), and somatosensory abnormalities 3 (3.8%) are examples of chronic neurological illnesses (Sofia et al., 2017).

Hg can accumulate in the human body through breathing because He has a vapor pressure at room temperature, besides that Hg can also accumulate through direct skin contact due to the activities of gold workers who do not use personal protective equipment (Kumar et al, 2021). If a person experiences mercury poisoning, they will experience symptoms such as tremor, headaches, difficulty swallowing, decreased memory, and blurred vision. Not only that, other symptoms that can arise from Hg poisoning are thick feet and hands, diarrhea, mouth congestion, and swollen gums (Priyambodo et al., 2020).

Mercury pollution has become an issue of international concern. The most famous case of mercury poisoning was the Minamata tragedy in Japan in 1950. Most of the population of the two coastal regions of Minamata, Kumamoto and Kagoshima, were victims of mercury poisoning. More than 2000 residents were affected by hand and foot numbness, weakened muscle strength, impaired coordination of movement, eye disorders, speech disorders, hearing loss, paralysis, and death (Aryantie et al., 2020).

Artisanal small-scale gold mining is practiced in numerous South American, Asian, and African nations. Due to the large number of rural residents employed in gold mining, Columbia is one of the nations that stands out for having the greatest levels of mercury contamination (Cordy et al., 2011). Its species can be identified in a number of biomarkers in order to ascertain the effect of mercury exposure on tiny, artisanal gold mining groups in Columbia. Due to its ease of collection and monitoring, hair is favored over blood and urine (Poulin et al., 2008). To assess ingested MeHg exposure from eating fish, total mercury assay in hair has historically been utilized (Salazar-Camacho et al., 2017). However, when exposed to contaminated air, mercury gas can also be directly absorbed into hair (Queipo Abad et al., 2016).

Since Indonesia is now one of the top ten gold-producing countries in the world, artisanal mining, which has been practiced there for hundreds of years, has become even more popular. In Indonesia, artisanal small-scale gold mining can be classified as either licensed or unlicensed. Due to a lack of government licenses, the majority of artisanal activities in Indonesia continue to operate illegally. Because it is unlicensed, does not pay royalties, damages the environment, and has negative health effects due to mercury use, this is deemed harmful to the nation (Meutia et al., 2022). In Indonesia, the majority of small-scale artisanal gold mining employs conventional techniques that include amalgamating mercury to extract gold. However, using poisonous mercury can have serious negative effects on the ecosystem and human health (Bagia et al., 2023)

Preliminary observations found that gold workers in Tallo District still use traditional methods and without personal protective equipment. The method of processing materials using mercury is still carried out freely by workers for a long period of time. Thus, allowing mercury that is wasted with waste to be distributed into water and soil and evaporate into the air has the potential to enter the food chain and threaten the health of workers. It also allows very high mercury exposure to workers that can cause neurological disorders.

MATERIAL AND METHODS

This study is a cross-sectional study conducted based on information obtained from laboratory results, health examinations by doctors and interviews using questionnaires. Sampling was conducted in May 2024 in Tallo sub-district, Makassar City. The interview consisted of questions relevant to the respondents such as age, education, job duties in gold processing, length of employment and compliance in the use of personal protective equipment.

There were 30 gold worker respondents who were willing to donate head hair and have their neurological symptoms examined by a doctor. In total, 30 gold workers met the inclusion criteria and agreed to participate in the study. Gold workers who were still active and male were the inclusion criteria, while the exclusion criteria were not gold workers and not willing to be respondents.

The total mercury concentration in hair samples collected from each respondent was examined in order to determine the degree of mercury exposure among gold workers. On the right side of the back of the head, 0.2 to 0.5 grams of hair were clipped from the occipital region near the skin. The

samples were then placed in a sample bag, labeled, and submitted to the lab for examination. ICP-MS was used to analyze hair samples. According to WHO guidelines, hair has demonstrated mercury toxicity if the toxicological threshold value is greater than $1\mu\text{g/g}$ or 2 ppm.

Thirty employees had their neurological complaints clinically evaluated. The doctor used the mercury health and environmental evaluation technique recommended by UNIDO to identify ten objective symptoms. Bluish discoloration of the gums, ataxia and rigidity, alternating movements or dysdiadochokinesia, irregular eye movements, visual field, knee jerk and biceps reflex, Babinski reflex and labial reflex, salivation and dysarthria, sensory examination, and tremor were among the ten neurological symptoms. By assigning a score of 1 for symptoms that were positively noticed and 0 for symptoms that were negatively observed, you can determine the symptoms that were observed. Next, tally the frequency of each symptom and the total number of symptoms that each person tested positive for.

Data Analysis

The independent variables were age, length of work, smoking habit, use of personal protective equipment, mercury concentration and neurological symptoms as dependent variables. Statistical analysis was performed using SPSS (Statistical Program for Social Science) version 25.0. Univariate, bivariate and multivariate analyses were conducted in this study. Univariate analysis provided descriptive statistics, including frequencies, percentages, and means, which were calculated for the variables. Bivariate analysis aimed to test the hypothesis of the relationship between independent and dependent variables in the form of crosstabs with chi-square statistics. Multivariate analysis to determine the relationship between several (more than one) independent variables with one or more dependent variables (generally one dependent variable).

The result of the chi-square test were then tested with logistic regression to obtain the independent variable that most strongly associated with neurologic symptoms among all independent variables. Calculation of the level of level or p-value of 5%. If the p-value $< \alpha = 0.05$ then there is an relationship between the independent variable and the dependent variable.

RESULT

Based on the results of Table 1, it can be seen that of the 30 respondents, the most respondents are respondents in the age range 36-45 years as many as 13 (43%) respondents, and the fewest respondents are respondents in the age range 56-65 years as many as 2 (7%) respondents. Based on the table above, respondents with a working period of > 5 years were 19 (63.3%) respondents, respondents with a working period of ≤ 5 years were 11 (36.7%) respondents. The working hours in a day of respondents were > 8 hours/day as many as 20 (66.7%) respondents and respondents with working hour's ≤ 8 hours/day were 10 (33.3%) respondents. As well as 63.3% of workers did not use personal protective equipment (PPE) during work and had a smoking habit of 76.7%.

Table1. Distribution of Respondents based on variables studied in Gold Workers in Tallo District, Makassar City

| Characteristics | n | % |
|------------------------|----|------|
| Age (year) | | |
| 26-35 | 7 | 23 |
| 36-45 | 13 | 43 |
| 46-55 | 8 | 27 |
| 56-65 | 2 | 7 |
| Working hours in a day | | |
| > 8 hours/day | 20 | 66,7 |
| ≤ 8 hours/day | 10 | 33,3 |
| Working Year (year) | | |
| >5 years | 19 | 63,3 |
| ≤ 5 years | 11 | 36,7 |
| Smoking habit | | |

| | | |
|--------------------------------------|----|------|
| Yes | 23 | 76,7 |
| No | 11 | 36,7 |
| Use of Personal Protective Equipment | | |
| Yes | 19 | 63,3 |
| No | 11 | 36,7 |

Source: Primary Data, 2024

Table 2. Frequency distribution table of neurological symptoms based on the examination of small-scale gold workers in Tallo District, Makassar City

| Neurological Symptoms | N | % |
|---|----|----|
| Sign of bluis discolorationof gums | 17 | 38 |
| Rigidity and ataxia (walking & standing) | 2 | 4 |
| Test alternating movements | 2 | 4 |
| Test for irregular eye movements | 8 | 16 |
| Field of vision test | 5 | 11 |
| Reflexes knee jerk reflex and biceps reflex | 4 | 9 |
| Phatology reflex: Babinski reflex and labial reflex | 1 | 2 |
| Salivation and dysarthria | 2 | 4 |
| Sensory examination | 4 | 9 |
| Tremor and Romberg test | 1 | 2 |

Source: Primary Data, 2024

Table 2 shows the frequency distribution of neurological symptoms based on the threshold limits of the Human Bio-monitoring Commission (HBM) of the German Federal Environmental Agency. Examinations were conducted directly at the study site and conducted by a physician. The results showed that each gold worker was diagnosed with a number of different symptoms. Three gold workers had four more neurological symptoms than the other workers, while nine gold workers showed negative results on all neurological symptoms examined. As shown in table 2, sign of bluish discoloration of gums was the most prevalent symptom among gold workers.

Table 3. Analysis of independent variables with small-scale gold workers in Tallo District, Makassar City.

| Variable | Neurological Symptoms | | P Values |
|-------------------------------|-----------------------|----------|----------|
| | Abnormal | Normal | |
| | % | % | |
| Age | | | |
| > 40 years | 14 (77,8) | 4 (22,2) | 0,114 |
| ≤ 40 years | 6 (50) | 6 (50) | |
| Working hours in a day | | | |
| > 8 hours/day | 12 (13,3) | 8 (6,7) | 0,273 |
| ≤ 8 hours/day | 8 (6,7) | 2 (3,3) | |
| Working year (year) | | | |
| >5 years | 16 (12,7) | 3 (6,3) | 0,007* |
| ≤ 5 years | 4 (7,3) | 7 (3,7) | |
| Smoking habit | | | |
| Yes | 15 (15,3) | 8 (7,7) | 0,760 |
| No | 5 (4,7) | 2 (2,3) | |
| Use of PPE | | | |
| Yes | 3 (7,3) | 8 (3,7) | 0,002* |
| No | 17 (12,7) | 2 (6,3) | |
| Mercury concenretation | | | |
| Normal | 5 (35,7) | 9 (64,3) | 0,001* |

| | | | |
|----------|-----------|---------|--|
| Abnormal | 15 (93,8) | 1 (6,2) | |
|----------|-----------|---------|--|

Source: Primary Data, 2024

Table 3 shows that the Chi-square test results between groups with neurological symptoms and without symptoms (normal), working period ($P=0.007$), PPE use ($P=0.002$) and mercury concentration ($P=0.001$) have a P -value <0.005 , which means that they have a significant effect on neurological symptoms. Age, length of service, and smoking habits had no significant effect on neurological symptoms.

Table 4. Multivariate analysis results of factors affecting neurological symptoms in gold workers in Tallo District, Makassar City

| Variable | B | P-value | OR | 95% CI for OR | |
|-----------------------|--------|---------|-------|---------------|--------|
| | | | | Lower | Upper |
| Use of PPE | -1.394 | 0,354 | 0,248 | 0,013 | 4,715 |
| Working year (year) | 1.754 | 0,097 | 5.780 | 0,726 | 45.990 |
| Mercury concentration | -2974 | 0,015* | 0,051 | 0,005 | 0,562 |
| Constant | 0.905 | 0,168 | 2,472 | | |

Source: Primary Data, 2024

According to Table 4, the variables of working period and PPE use have sig values of $p=0.097$ and $p=0.354$, which means that both variables are not meaningful. Mercury concentration variable with the lowest sig value compared to other variables. It can be concluded that the most dominant variable affecting neurological symptoms is mercury concentration $p=0.015$.

DISCUSSIONS

Age may influence the presence of mercury in the body, as the increasing age increases the risk of accumulated mercury exposure, especially in the elderly. When a person reaches old age, the function of organs such as the kidneys, liver, and brain decreases, making them vulnerable to substances that enter the body (Bagia et al., 2023). The chi-square test of the effect of age on neurological symptoms $P=0.114$ showed no significant effect between age and neurological symptoms in gold workers. The opposite findings from research in Ecuador showed a relationship between age and neurological examination results such as workers experiencing tremors (Zaharani & Salami, 2015).

The length of time a person works properly in a day is generally 6-8 hours per day. Extending the working time beyond the worker's ability will lead to fatigue, health problems, accidents and dissatisfaction (Harari et al., 2012). Gold workers in Tallo Sub-district are dominated by workers who have a working time of more than 40 hours per week, ranging from 42-60 hours per week. This working time exceeds the normal working hours limit of 40 hours per week or 8 hours per day with 5 working days. The longer gold workers work, the longer the duration of their exposure to elemental and compound mercury.

In general, the length of work of gold workers in Tallo District starts from 07.00 to 17.00 and continues at 19.00 to 23.00 at night depending on the availability of raw materials that can be processed on that day. The results of the hypothesis using chi-square obtained that the variable length of work $P=0.494$ ($P > 0.05$) means that there is no influence between the length of work with neurological disorders in small-scale gold workers in Tallo District, Makassar City.

The working period is related to the accumulation of chemicals in the human body. Gold workers are generally exposed to mercury through skin contact and inhalation of mercury vapor during the processing of materials used to produce gold. The adverse effects of mercury and methyl mercury on a person's health are not immediately apparent. However, the effects of continuous exposure will be seen over time. The adverse effects of mercury exposure will be seen about five to ten years after exposure. Numerous organs and metabolic processes are said to be impacted by mercury intoxication. Neurological symptoms like tremors, ataxia, memory issues, and vision impairment are the most often reported side effects of mercury poisoning in gold miners (Gibb & O'Leary, 2014).

According to the examination of the relationship between working hours and neurological symptoms, $P = 0.007$ ($P < 0.05$) suggests that working hours have an impact on neurological

symptoms in Tallo District's small-scale gold workers. According to earlier research, gold miners who work longer hours are more likely to be exposed for longer periods of time, which leads to a higher buildup of mercury in their bodies. In this study, the miners experienced several clinical symptoms that were considered as clinical symptoms of hg poisoning. These symptoms included shaking hands and head, numbness, headache, respiratory problems, and joint pain (Mercy et al., 2020). The number of smokers among gold workers in Tallo District was 54.2% while 45.8% were non-smokers. Workers who were active smokers were found to experience neurological symptoms as much as 15.3%.

The chi-square test showed $P=0.760$ which means there is no influence between smoking habits and neurological symptoms in small-scale gold workers in Tallo District, Makassar City. Discoloration of the gums during the examination of health symptoms is one of the factors of smoking habits. Some gold workers explained that they had been actively smoking since a young age. Neurological complications due to smoking are caused by nicotine. Hundreds of harmful substances included in cigarette smoke have been linked to lung and cardiovascular disorders as well as cancer. Numerous neurological issues, from cognitive loss to catastrophic stroke, can result from repeated exposure to these poisons. Tavee (2012) According to the Indian National Brain Research Center, cigarette smoke contains chemicals that agitate white blood cells in the central nervous system (CNS), leading them to collide with healthy cells and cause neurological damage.

The use of personal protective equipment (PPE) is very influential to reduce the risk of occupational accidents and avoid occupational diseases such as neurological symptoms that are in line with the findings in this result ($P = 0.002$). Generally, small-scale gold workers in Tallo District do not use personal protective equipment with a percentage of 63.3% compared to workers who use it with a percentage of 36.7%. In the upper eastern region of Ghana, a study of 120 miners revealed that only 5.8% of workers used personal protective equipment, while 70% never used it at all (Paruchuri et al., 2010). This is similar to studies conducted in various locations in Ghana which show that the majority of gold miners never wear any personal protective equipment (Siabi et al., 2022).

The high non-compliance in the use of personal protective equipment is due to the low level of education and lack of training on mercury toxicity among gold workers. The influence between the use of personal protective equipment and neurological symptoms can be caused by 70% of workers not wearing PPE when in direct contact with mercury so that hg easily enters the body and accumulates in the brain and then distributes to the nerves, if there is hg resistance in the central nervous system and peripheral nervous system, neurological disorders will occur.

The results of the examination of mercury concentration in the hair of small-scale gold workers in Tallo District have an influence on neurological symptoms ($P = 0.001$). Based on the results of laboratory examinations, out of 30 respondents, 53.3% of the accumulation of metal mercury in the hair of workers exceeded the threshold value set by WHO and as many as 46.7% were still within normal limits. Other analysis results found that the percentage of gold workers who had mercury concentrations in the high category and experienced neurological symptoms was 93.8%.

This study is in line with previous research showing that urinary mercury levels and neurological problems are directly proportional. When mercury levels are high, neurological problems are found in gold workers. The results of previous research in the same location show that goldsmiths have experienced various neurological symptoms. Neurological problems that occur in goldsmiths are caused by the use of mercury in the process of gold color purification. There are 68.6% of goldsmiths who experienced neurological symptoms. The highest symptoms found was discoloration of the gums with a percentage of 34.4% and 48.6% of goldsmiths who used mercury in gold management (Suhelmi et al., 2020).

Gold workers who use mercury have 3.876 times the risk of neuropsychological disorders compared to those who do not use mercury. The symptoms found were often forgetting with a percentage of 34.4% followed by tremors at 8.6%. Mercury enters the body through inhalation and will be inducted into the brain through Reactive Oxygen Species (ROS). These ROS will then alter the antioxidant cell defense system. Furthermore, there is a detoxification process in the body involving glutathione (Aras et al., 2024).

CONCLUSION

This study looked at mercury exposure in gold workers in Tallo District, Makassar City. Mercury concentration is the most dominant determinant of neurological symptoms. The concentration of mercury in the hair of gold workers has exceeded the established threshold value and workers with high mercury levels are diagnosed with a number of neurological symptoms. Mercury concentrations tend to increase with increasing years of work and unawareness of the use of personal protective equipment.

Ethical approval by the Public Health Faculty, Hasanuddin University (Number: 974/UN4.14.1/TAP.01.02/2024). Before data collection and interviews, the researcher explained the research objectives, methods and written consent.

Availability of data and material: Data sharing not applicable - no data shared, or the article describes entirely theoretical research.

Competing interest: The authors declare that there are no conflicts of interest.

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