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Identification of Mercury Levels and Disease Symptoms in Workers at Traditional Gold Mining Sites in the Working Area of Public Health Centre Ujung Padang Rasian

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ABSTRACT

This research aims to identify the symptoms of diseases experienced by gold mine workers due to mercury exposure in the Public Health Centre Ujung Padang Rasian work area, South Aceh Regency, Aceh Province. This study used a cross-sectional approach involving 39 respondents, and mercury levels were analyzed using an Atomic Absorption Spectrofotometry (AAS) instrument. Based on the research findings, most workers experienced acute clinical symptoms such as headaches (34 respondents), coughs, and pain during urination (24 respondents). Chronic toxicity symptoms recorded included somatosensory disturbances in gold processing workers. Muscle cramps (17 respondents) and headaches (16 respondents) were the most common complaints among workers. Mercury level measurements showed that the average mercury level in workers' urine was 207.6 µg/L. The mercury content in the studied urine samples exceeded the threshold Human Biomonitoring (HBM) set of 7 µg/L. The correlation testing indicated that mercury levels in urine correlated with several acute and chronic disease symptoms experienced by workers, such as ulcers (P value = 0.007), tongue swelling (P value = 0.007), olfactory loss (P value = 0.007), hearing disorders (P value = 0.007), and tremors (P value = 0.007). Based on the research findings, it can be concluded that more than half of the workers had mercury levels in their urine exceeding the threshold, and these mercury levels also correlated with several symptoms of diseases experienced by the workers.

Keywords: Mercury, Workers, Health, Community, Disease Symptoms

INTRODUCTION

According to the World Health Organization (WHO, 2017), mercury is currently among the ten most hazardous chemicals to public health. Human activities have increased the total mercury concentration in the atmosphere by about 450% above its natural levels. This increase is reflected in the mercury content found in various aquatic food chains (UN Environment, 2019). In October 2013, 92 countries signed the Minamata Convention on Mercury, an international agreement aimed at reducing environmental contamination by mercury and preventing and addressing cases of human poisoning with this metal (Crespo-Lopez *et al.*, 2021).

Mercury is classified as a hazardous substance under the Hazardous and Toxic Materials (B3) category due to its potential harm to living organisms and environmental pollution (Kusumawaty *et al.*, 2022). It is one of six heavy metals known for its high toxicity to human health and the environment (Setiyono and Djiaidah, 2012). In Indonesia, several cases of mercury pollution have been associated with illegal gold mining activities in regions such as Kalimantan and Papua. Gold mining in Indonesia is a significant natural resource with a long history dating back to the Dutch colonial era. One notable gold mine during that time was the Pongkor gold mine in West Java. Following Indonesia's independence, the management of gold mines came under the control of the Indonesian government (Soedjatmiko. 2008).

Sources of mercury pollution can be broadly categorized into two main types: those originating from natural sources and those from mining activities. According to Beras et al. (2014), mercury exists naturally in the environment and can also be a contaminant due to human activities (Kamil and Karma, 2022). Natural sources of mercury include mercury mines, where some mines worldwide produce mercury as a byproduct of mining other metals. Notable examples of natural mercury sources include the Almadén mine in Spain and the Nikel mine in Russia (Svetlana N. 2005).

Mercury enters the body through food chains and water, causing poisoning if tolerance limits are exceeded (Lensoni et al., 2020). Approximately 80% of mercury vapor enters the body through inhalation, with only a small amount of elemental mercury (Hg^0) entering through skin contact and ingestion (Adlim, Kamil, and Karma, 2023). When absorbed through the respiratory tract, gastrointestinal tract, or skin, mercury compounds dissociate, producing mercury ions upon entering the bloodstream. Subsequently, mercury ions accumulate in the brain and kidneys, leading to damage in multiple organs, including the kidneys, nerves, cardiovascular, and nervous systems (Chan TY, 2011). Due to mercury's strong affinity for kidney tissues, the kidneys are particularly vulnerable to mercury poisoning. Accumulating mercury in the body to a certain level leads to kidney diseases reflected in proteinuria and toxic encephalopathy. Clinically, patients with kidney damage due to mercury poisoning typically exhibit edema, changes in urine volume, proteinuria, and/or nephrotic syndrome in addition to typical clinical signs of mercury poisoning such as irritation, gingivitis, and tremors (Bensefa-Colas L *et al.*, 2011).

According to the Blacksmith Institute (2015), an estimated 19 million people worldwide are at risk of mercury exposure, posing a global public health challenge. The mercury poisoning incidents have been known since the 1960s, notably in Minamata, Japan, where 111 fatalities occurred between 1953 and the 1960s, and in Iraq, where 35 fatalities and 321 injuries were recorded in 1961. In Pakistan, there were 4 fatalities and 34 injuries in 1963, 20 fatalities and 45 injuries in 1966, and in Niigata, Japan, there were 5 fatalities and 25 injuries in 1968. (Crespo-lopez *et al.*, 2021). Traditional gold mining can bring both positive and negative changes. Positive changes include increased income for communities, entrepreneurs, and governments, while unfavorable changes can damage the environment and cause health disorders such as neurological symptoms. Neurological symptoms are related to disorders in the nervous system, both central and peripheral, as a result of exposure to toxic substances, including mercury (Bagia *et al.*, 2023). Exposure to mercury levels can damage organs such as the kidneys and brain and can also harm developing fetuses (Adhani and Husaini, 2017). Most foods and beverages contain mercury levels ranging from <1 to 50 mg/kg, which can be higher in seafood (Adhani & Husaini., 2017).

Lensoni *et al.'s* (2022) research titled "Description of Mercury Poison Clinical Symptoms in Workers and Communities Around the Small-Scale Gold Processing Area" indicates that the most commonly experienced acute clinical symptoms among gold mine workers were coughing (8 respondents), pelvic pain, diarrhea, abdominal pain, vomiting, nausea, and headache (7 respondents). Chronic clinical symptoms experienced by workers included headaches and difficulty sleeping (8 respondents), irritability (6 respondents), anxiety (6 respondents), cramps (5 respondents), and tremors (4 respondents).

METHODS

Research Location

This study was conducted at a traditional gold processing site in the working area of the Padang Rasian Health Center in South Aceh Regency, Aceh Province.

Population and Sample

The respondents in this study were selected using the total sampling method, encompassing all workers at the traditional gold processing site

Ethical

The protocol in this study received ethical approval through letter No.076/KEP-UNISM/IX/2023 (dated September 9, 2023) from the Research Ethics Commission of Sari Mulia University, Banjarmasin.

Identification of Disease Symptoms in Workers

Analysis of the symptoms experienced by workers was conducted using a questionnaire provided by the World Health Organization (WHO), which other researchers have also used to analyze similar cases in different locations (Sofia, Ibrahim, and Risqa, 2017; Kamil and Karma, 2022).

Analysis of Mercury Levels in Workers' Urine

The urine samples were taken from respondents who had previously completed the questionnaire. The urine samples were obtained in accordance with the Regulation of the Minister of Health of the Republic of Indonesia Number 43 of 2013. Before analysis, the samples were preserved by adding HNO_3 solution and stored at 4 °C (Lensoni *et al.*, 2023).

The prepared urine samples will be measured for mercury levels. The samples were tested based on SNI 6989.78-2011 concerning the method for testing mercury (Hg) using Cold Vapor Atomic Absorption Spectrophotometry (CV-AAS) (Adlim, Kamil, and Karma, 2023).

RESULTS AND DISCUSSION

Respondents' Demographic Data

The study results indicate that out of 39 respondents, 36 were male, and 3 were female. In terms of educational level, it was found that most workers had a primary education level, as presented in Table 1.

Table 1
Respondents' Demographic Data

Criteria	f
Gender	
Men	36
Women	3
Education Level	
Elementary school	16
Junior high school	11

Senior High School	10
Bachelor	2
Age	
12-16 Year	1
17-25 Year	5
26-35 Year	9
36-45 Year	9
46-55 year	9
56-65 year	3
>65 Year	3
Work Tenure.	
1-5 Year	26
6-10 Year	9
10-15 Year	4

Identification of Disease Symptoms in Workers

This study identified disease symptoms experienced by workers at the traditional gold processing site, including acute and chronic medical symptoms. The results of identifying acute disease symptoms experienced by the workers are shown in Figure 1.

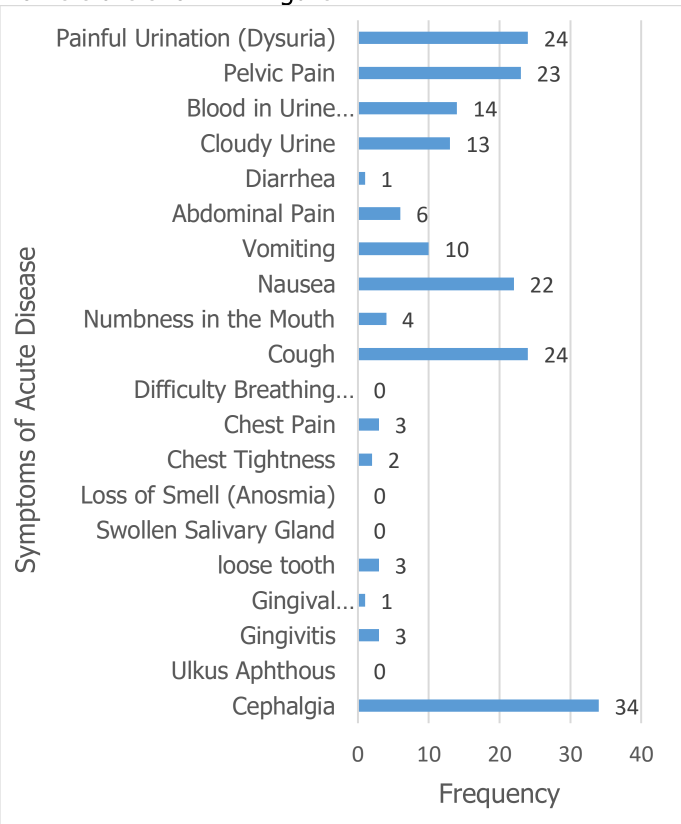

Figure 1. Workers' Acute Clinical Symptoms

Based on Figure 1, the acute clinical symptoms experienced by workers were predominantly headaches (34 respondents), coughing, and painful urination (24 respondents each). Meanwhile, Figure 2 depicts the analysis of chronic toxicity symptoms, which included somatosensory disturbances among gold processing workers. Most workers experienced muscle cramps (17 respondents) and headaches (16 respondents).

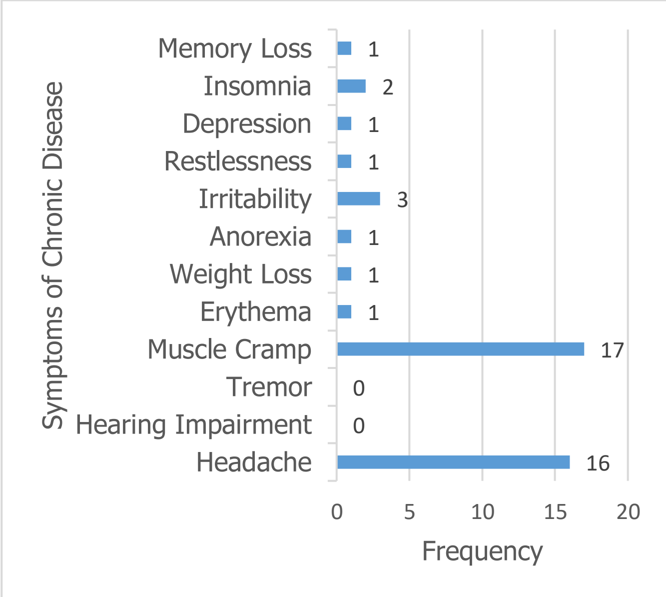

Figure 2. Workers' Chronic Clinical Symptoms

Other researchers have also reported previous research results regarding the symptoms experienced by amalgamation gold processing workers. The study's findings indicate that gold milling operations conducted by communities have an impact on worker health. According to (Lensoni *et al.*, 2022), acute clinical symptoms most commonly experienced by gold mine workers include coughing (8 respondents), pelvic pain, diarrhea, abdominal pain, vomiting, nausea, and headache experienced by 7 respondents. Meanwhile, chronic clinical symptoms among workers include headaches and difficulty sleeping (8 respondents), irritability (6 respondents), anxiety (6 respondents), muscle cramps (5 respondents), and tremors (4 respondents). Additionally, chronic toxicity symptoms recorded include somatosensory disturbances among gold processing workers. The majority of workers experience headaches and insomnia (8 respondents), irritability (6 respondents), anxiety (6 respondents), muscle cramps (5 respondents), and tremors (4 respondents). (Lensoni *et al.*, 2022).

Other researchers have also reported previous research results regarding the symptoms experienced by amalgamation gold processing workers. The study's findings indicate that gold milling operations conducted by communities have an impact on worker health. Nearly half of the workers reported experiencing acute symptoms such as fatigue (41.7%), headaches (39.6%), and mouth numbness (39.6%). Meanwhile, chronic clinical symptoms included muscle cramps (43.8%), headaches (41.7%), irritability (39.6%), and sadness (33.3%) (Suhendrayatna *et al.*, 2014). Da Silva-Junior et al. (2018) examined symptoms of mercury exposure in communities around the Amazon River. They found that visual disturbances had the highest prevalence (43.3%), followed by complaints of memory loss (42.9%), weakness (35.1%), fatigue (34.3%), mood changes (28.7%), and concentration difficulties (27.2%) (Adlim, Kamil and Karma, 2023).

The study by Sofia et al. (2017) indicated neurological disorder symptoms as a result of mercury exposure, such as acute neurological disorders including headaches (48.7%), emotional lability (9.0%), and hearing impairment (3.8%). Meanwhile, chronic neurological disorders experienced were insomnia (37.2%), tremors (10.3%), memory loss (9.0%), and somatosensory disturbances (3.8%)(Sofia, Ibrahim and Risqa, 2017). Suhelmi et al. (2020) found that the highest neurological symptom reported was a change in gum color (34.3%), followed by tremors (11.4%) and changes in gum color and physiological reflexes (14.3%) (Suhelmi *et al.*, 2020).

Identification of Mercury Levels in Workers' Urine

The identification of mercury levels in the urine of gold processing workers was performed using Atomic Absorption Spectroscopy (AAS). The instrument was calibrated by creating a calibration curve using standard mercury solutions, which resulted in an R-value of 0.9905. This indicates that the instrument is functioning well when measuring mercury levels in urine. Subsequently, mercury levels were measured in 39 urine samples from workers, with the results shown in Figure 3.

Figure 3 shows that some urine samples have mercury levels exceeding the upper threshold set by Human Biomonitoring (HBM), which is 7 µg/L (Schulz *et al.*, 2007). The high mercury levels in workers' urine may be attributed to several factors based on previous research reports. One such factor is the duration of employment, as Li *et al.* (2009) reported, which indicates that prolonged mercury exposure increases the concentration of mercury in the body and can lead to acute and chronic toxicity.

High mercury levels in workers' urine can also be understood through the exposure methods experienced by the workers. Very little elemental mercury (Hg0) enters the human body through skin contact or oral ingestion; approximately 80% of mercury vapor enters the body through inhalation. When amalgam is heated, anyone near the burning site can be exposed to the mercury vapor produced. Therefore, it can be concluded that the high mercury levels in workers' urine are likely due to prolonged exposure.

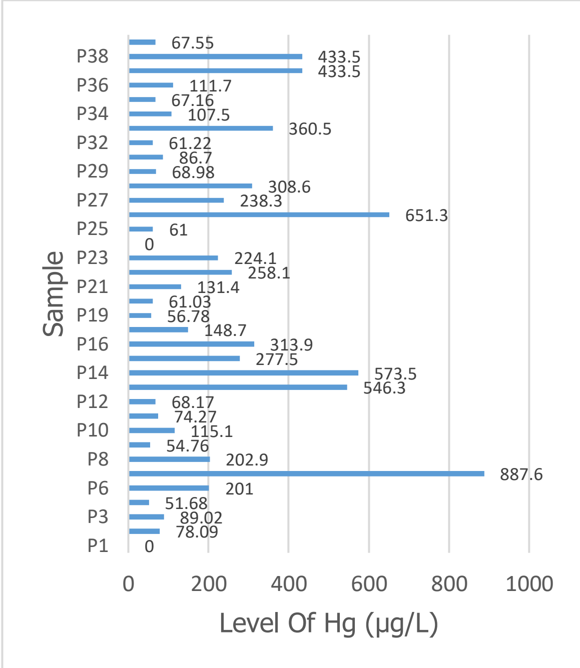

Figure 3. Distribution of Mercury Levels in Workers' Urine

Correlation Test of Mercury Levels with Disease Symptoms Experienced by Workers

Given the high mercury levels in some of the urine samples, examining whether there is a correlation between mercury levels in workers' urine and the disease symptoms experienced by workers at the traditional gold processing site is necessary.

Table 2

Results of the Correlation Test between Mercury Levels and Chronic Disease Symptoms in Workers

No		1		2		3		4		5		6	
Disease Symptoms		Headache		Hearing disorder		Tremor		Muscle cramp		Erythema		Weight loss	
		No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Urinary Mercury Concentration	n	23	16	39	0	39	0	22	17	38	1	38	1
	%	59	41	100	0	100	0	56.4	43.6	97.4	2.6	97.4	2.6
Total Respondents	n	23	16	39	0	39	0	22	17	38	1	38	1
	%	59	41	100	0	100	0	56.4	43.6	97.4	2.6	97.4	2.6
Pvalue		0,133		0.007		0.007		0,451		0.358		0.358	
No		7		8		9		10		11		12	
Disease Symptoms		Anorexia		Irritability		Anxiety		Depression		Sleep difficulty		Memory loss	
		No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Urinary Mercury Concentration	n	38	1	36	3	38	1	38	1	37	2	38	1
	%	97.4	2.6	92.3	97.4	2.6	97.4	2.6	97.4	94.9	5.1	2.6	97.4

Total	n	38	1	36	3	38	1	38	1	37	2	38	1
Respondents	%	97.4	2.6	92.3	7.7	97.4	2.6	97.4	2.6	94.9	5.1	2.6	97.4
Pvalue		0.327		0,358		0.358		0.358		0.864		0.358	

The mercury levels in urine were found to correlate with several acute (table 3) and chronic (Tabel 2) symptoms experienced by workers, such as ulcers (P value = 0.007), tongue swelling (P value = 0.007), olfactory loss (P value = 0.007), hearing disorder (P value = 0.007), and tremor (P value = 0.007) The test results indicate that some respondents have a significant correlation between mercury levels and the disease symptoms experienced. This is consistent with previous research, which found no significant relationship between mercury levels and blood profile indicators such as hematocrit (p-value = 0.380), erythrocytes (p-value = 0.529), MCV (p-value = 0.641), MCH (p-value = 0.351), platelets (p-value = 0.501), and hemoglobin (p-value = 0.334) in traditional gold miners in Wonogiri Regency. However, a significant relationship was found between mercury (Hg) levels in the blood and leukocytes (p-value = 0.017) (Aryani, Setiani, and Nurjazuli, 2013). In another study conducted by Lestarisa (2010) on factors associated with mercury poisoning in traditional miners, chi-square analysis showed that two independent variables—length of workdays (p = 0.002) and continuous use of personal protective equipment (PPE) (p = 0.000)—had a significant relationship with mercury poisoning in illegal gold miners (PETI). Symptoms identified in PETI include fatigue, headaches, tremors/chills, and joint stiffness (Basu, 2023).

The high mercury levels found in urine can enter the body through various pathways, as Ye *et al.* (2016) mentioned. Mercury exposure pathways include (a) food consumption, (b) inhalation or absorption (through the skin) of mercury vapor at the workplace, (c) exposure during industrial and household waste processing, and (d) use of pharmaceutical or cosmetic products (Kim, Kabir and Jahan, 2016). Similarly, mercury entering the human body through routes such as the digestive system, respiratory system, and skin is absorbed at varying rates depending on the form of mercury compound. In 2012, the Korean Food and Drug Administration (KFDA) reported different exposure media contribution levels for various age groups based on mercury concentration data in food. According to the report, the contribution levels of inhalation exposure from air were 0.47-0.83%, drinking water (tap water) 0.01-0.02%, and soil consumption 0.03-0.32%, with the highest levels observed in infants and young children. The study also reported that the primary medium of mercury exposure is food, as indicated by the fact that mercury exposure through food consumption accounted for 98.85-99.48% (Ye *et al.*, 2016; Silva *et al.*, 2023).

Urine mercury concentration is very stable and relatively straightforward due to the characteristics of the medium (Basu *et al.*, 2018; Esteban-López *et al.*, 2022). Additionally, it provides a quick method for identifying individuals exposed to mercury. However, since organic mercury constitutes only a small portion of urinary mercury, urine is more useful for analyzing inorganic or elemental mercury compounds. Moreover, workers exposed to mercury over a long period exhibit high levels of urinary mercury for extended durations, similar to blood mercury concentrations, due to the body's mercury burden (Klaassen, 2013). When urinary mercury concentrations exceed 100 µg/L, neurological symptoms may develop, and levels of 800 µg/L or higher can be fatal. Organic mercury, such as methylmercury, is typically excreted through feces. Therefore, urinary mercury levels may not accurately reflect the concentration of organic mercury in the body (Goldman and Shannon, 2001).

The relationship between mercury levels and disease symptoms has previously been reported by Yard *et al.* (2012). Research conducted on 103 individuals living in a gold mining area, including 35 people who had direct contact with mercury at least once a month, found that over 50% reported symptoms such as headaches, mood changes, or muscle weakness. Previous medical diagnoses included gastrointestinal disorders (n = 20), renal dysfunction (n = 9), and neurological disorders (n = 4). Participants reporting renal dysfunction had higher total urinary mercury concentrations (GM = 12.0 µg/g-creatinine) compared to those not reporting renal dysfunction (GM = 5.1 µg/g-creatinine; $p < 0.05$). Urinary mercury concentrations were significantly higher ($p < 0.05$) among individuals who heated amalgam compared to those who never heated amalgam.

Harari *et al.* (2012) study mentions that out of 200 gold miners, 37 gold traders, and 72 references, tremors were experienced, and this symptom was found to be associated with blood mercury and urinary mercury levels. Mercury elimination appears to be influenced by polymorphism. Gold traders had the highest levels of blood and urinary mercury because they burned amalgam every day. Another study conducted by Tomicic *et al.* (2011) Tom's study reported that nearly half of the 93 workers considered most vulnerable to mercury exposure reported five symptoms potentially related to mercury exposure: frequent headaches, sleep disturbances, dizziness, mouth sores/irritation, unusual fatigue, difficulty walking, tremors, tingling in hands or feet, vision disturbances, persistent cough, chest pain, and rhinitis. Gold traders were found to have higher urinary mercury levels compared to ore washers; dealers heated mercury an average of 13.2 times per day, compared to individuals who did not sell gold and heated mercury 7.8 times per day.

Table 3

Results of the Correlation Test between Mercury Levels and Acute Disease Symptoms in Workers

No		1		2		3		4		5		6		7		8		9		10	
Disease Symptoms		Headache		Ulcer		Swollen gum		Dark gum		Falling teeth		Swollen Salivary Gland		Olfactory loss		Shortness of Breath		Chest Pain		Breathing Difficulty	
		No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Urinary Mercury Concentration	n	5	34	39	0	36	3	38	1	36	3	39	0	39	0	37	2	36	3	39	0
	%	12.8	87.2	100	0	92.3	7.7	97.4	2.6	92.3	7.7	100	0	100	0	94.9	5.1	92.3	7.7	100	0
Total Participant	n	5	34	39	0	36	3	38	1	36	3	39	0	39	0	37	2	36	3	39	0
	%	12.8	87.2	100	0	92.3	7.7	97.4	2.6	92.3	7.7	100	0	100	0	94.9	5.1	92.3	7.7	100	0
P-value		0,483		0.007		0,315		0,488		0,165		0.007		0.007		0,492		0.977		0.007	

No		11		12		13		14		15		16		17		18		19		20	
Disease Symptoms		Coughing		Numb mouth		Nausea		Vomiting		Stomachache		Diarrhea		Cloudy urine		Hematuria		Hip pain		Dysuria	
		No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
2. Mercury In Urine	n	15	24	35	4	17	22	29	10	33	6	38	1	26	13	25	14	16	23	15	24
	%	38.5	61.5	89.7	10.3	43.6	55.4	74.4	25.6	84.6	15.4	97.4	2.6	66.7	33.3	64.1	35.9	41	59	38.5	61.5
Total Respondents	n	15	24	35	4	17	22	29	10	33	6	38	1	26	13	25	14	16	23	15	24
	%	38.5	61.5	89.7	10.3	43.6	55.4	74.4	25.6	84.6	15.4	97.4	2.6	66.7	33.3	64.1	35.9	41	59	38.5	61.5
Pvalue		0,961		0,623		0,694		0,902		0,714		0,989		0,875		0.610		0,588		0,528	

Based on the above description, it can be concluded that although mercury levels in urine may be high, this does not necessarily contribute to health conditions, as each individual has different physical conditions, resulting in varying effects of mercury levels on each person.

CONCLUSION

Based on the research findings, the majority of workers experienced acute clinical symptoms such as headaches (34 respondents), coughing, and painful urination (24 respondents). Chronic toxicity symptoms recorded include somatosensory disturbances among gold processing workers. Muscle cramps (17 respondents) and headaches (16 respondents) were the most prevalent among the workers. The average mercury level in the urine of the control group workers at the gold processing site was 18.21 µg/L, with minimum and maximum urine levels detected in participants being 11.4 µg/L and 30.39 µg/L, respectively. In contrast, the average mercury level in the test group was 207.6 µg/L. The results of this study should serve as a collective reminder to pay attention to the health status of traditional gold miners.

SUGGESTION

To monitor workers' health, routine examinations for traditional gold miners should be conducted, and education on the dangers of mercury use should also be implemented. From the above mercury content data, it can be concluded how dangerous the use of mercury is in gold mining. Therefore, it is recommended that workers use complete personal protective equipment (PPE) such as helmets, gloves, safety shoes, safety glasses, reflective vests, mining lamps, respirators, SCSR, and ear protection devices when processing gold. Further research is needed to determine whether the impact of mercury from traditional gold processing sites has affected the surrounding community.

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