بسم الله الرحمن الرحيم

**Republic of Sudan**

**Ministry of Higher Education and Scientific Research**

**Nile Valley University**

**College of Graduate Studies**

# Assessment of Mercury levels in Blood Samples Among Sudanese Workers in Abu Hamad Traditional Gold Mining Area in River Nile State /Sudan

A Thesis Submitted to the College of Graduate Studies in the partial of the Requirements for the Degree of

Master of Science in Analytical Chemistry

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# الآيـــــــــــة

بسم الله الرحمن الرحيم

﴿ فَتَبَسم ضاحكا من قولها وقال ربي أَوزعني أَنْ أَشكر نعمتك

التي أنعمتَ علي وعَلى والدي وأَنْ أَعمل صالحاً ترضاه وأَدْخلني

برحمتك في عبادك الصالحين ﴾

صدق الله العظيم

سورةالنمل الآية (19)

# Acknowledgement

Great thanks to Allah the Lord of the universe for giving me assistance, ability and patience to fulfill this work.

I would like to express my deep and sincere gratitude to Prof . Mutasim Elhussien for his valuable supervision and guidance. As supervisor ,his insight, observations and suggestions helped me to establish the overall direction of the research and to achieve the objectives of the work.

Finally, I am forever indebted to my small and big family for their encouragement since the beginning of this research.

Dedication

To my Father God give him along life , and to all To the soul of my Mother my Friends who supported me to continue , to my Wife encourage me. To Tgwa and Hayat) everyone who helped me. to my my daughters (Mayar , dear Dalal.

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# Abstract

Mercury is he one of the major heavy metals that can cause harm to the human body throughout Its exposure. In this study a sensitive enough Inductive Coupled Plasma Emission technique was used to quantify total mercury levels in blood of Traditional gold mining workers at Abu Hamad area, River Nile State – Sudan, during October 2019 – March 2020. eighteen samples concentrations were determined according to four different exposure compared to a control one. The obtained results showed that, the highest level of total mercury 2775 $\mu$g/l, in washing workers, while concentrations of 2600 $\mu$g/1405 $\mu$g/l, and 842.5 $\mu$g/l were determined in workers in shops ,Mills and burning respectively compared with 29.0 $\mu$g/l for the reference sample. The study also showed a relationship between total mercury concentration and staying limits as in the gold mining area to find incidents of neurological symptoms headache feeling stress, feeling weakness and Eye problems .The exposure resulting from inappropriate using of mercury. This study indicated that, the gold miners in Abu hamad area had been exposed to high Toxics levels of mercury.

# المستخلص

يعتبر فلز الزئبق من المعادن الثقيلة الرئيسية التي يمكن أن تلحق الضرر بجسم الإنسان طوال فترة تعرضه له. في هذه الدراسة ،تم استخدام تقنية انبعاث البلازما المقترنة الحساسة بدرجة كافية لقياس مستويات الزئبق الكلية في دم عمال مناجم الذهب في منطقة التعدين التقليدي في ابوحمد ، ولاية نهر النيل – السودان، خلال أكتوبر 2019 – مارس 2020م. تم تحديد عدد ثمانية عشر عينة تركيز الأربعة عينات مختلفة. التعرض مقارنة مع عينة مرجعية. وأظهرت النتائج المتحصل عليها أن أعلى مستوى للزئبق الكلي 2775 ميكروغرام / لتر في العمال الذين يعملون في الغسيل ،بينما تم تحديد التراكيز 2600 ميكروغرام / لتر و 1405 مايكرو غرام / لتر و 842.5 مايكرو غرام / لتر في العمال الذين يعملون في المحلات والمطاحن والمحارق على التوالي مقارنة بـ 29.0 مايكرو غرام / لتر للعينة المرجعية. أظهرت هذه الدراسة أيضًا وجود علاقة بين تركيز الزئبق الكلي وفترة البقاء للعمال كما هو الحال في منطقة تعدين الذهب للعثور على حوادث أعراض عصبية وصداع وشعور بالضغط والشعور بالضعف ومشاكل في العين و ذلك للتعرض الناتج عن الاستخدام غير الملائم للزئبق .أشارت هذه الدراسة إلى تعرض عمال مناجم الذهب في منطقة ابوحمد لمستويات عالية السمية من الزئبق.

# Chapter One

# Introduction

## 1.1 Background:

Mercury concentration in the blood is one of mercury exposure biomarkers. Detection of mercury in biological samples such as blood, urine and hair samples . This study conducted in a Abuhamad mining area in River Nile State , Sudan, during the period between October 2019 to February 2020 . The aim of the study is to evaluate serum mercury levels in traditional gold miners. The study will include two subjects, one of them who working in the gold mining area, beside healthy volunteer from River Nile State, as control group.

## 1.2 Introduction:

The first mining boom episode in Sudan gold, iron ore and copper mining activities in Nubia since 3000-1500 BC million miners participated, with 4 million family dependents benefited from mined gold revenues. The traditional gold mining activities cover 14 of the 18 Sudanese states. In 2014, the government produced over 60 tons of gold, which make Sudan ranked Africa's third-largest gold miner, and pushed it into the top 15 global producers [1,3] With recent estimates indicating there are as many as 19 million artisanal small gold (ASGM )miners[4, 5] mercury use and emissions in ASGM is clearly a global health problem [6].The heavy metals cadmium, lead, and mercury are common air pollutants emitted. Occupational mercury intoxication occurred frequently in the workers of the hat manufacturing factories of Europe in the nineteenth century. mainly as a result of various industrial activities. Mercury vapor can elicit the nephritic syndrome, characterized by excessive loss of protein (mainly albumin) in the blood, and edema[7,8].

Mercury-based artisanal and small-scale gold mining (ASGM) causes more mercury pollution than any other human activity [ 9]. mercury metal is used to extract gold from ore as a stable amalgam, The amalgam is then heated to evaporate the mercury and isolate the gold. While mercury amalgamation has been used for thousands of years to mine gold and silver[10]. it is unfortunately.

## 1.3 Rationale and Objectives

Rationale traditional gold mining using mercury to form gold amalgam is widely used in South America, Africa, and Asia. Many studies had assessed the mercury level, determined health effects, and investigated the health risk due to its exposure worldwide. In Sudan, the gold mining activities are spread However, there is only a few studies covering this area So, this study can conduct .

## 1.4 General Objective

To Assessment mercury levels in the blood among Sudanese traditional gold mining workers in Alabeedya .

## 1.5 Specific objective

• To detect mercury exposure among miners and one non-miner as reference .

• To measure the concentration of mercury in blood among gold mining worker.

• To observe the general toxicity among the gold mining worker.

• To observe the health effect of mercury in gold mining worker.

## 1.6 Mercury

Mercury is a chemical element with the symbol Hg and atomic number 80. It is commonly known as quicksilver and was formerly named hydrargyrum [11] Mercury is a heavy, silvery-white liquid metal compared to other metals, it is a poor conductor of heat, but a fair conductor of electricity It has a freezing point of −38.83 C° and a boiling point of 356.73 C°,[12][13][14] both the lowest of any stable metal, although preliminary experiments on copper znicium and flerovium have indicated that they have even lower boiling points copper znicicum being the element below mercury in the periodic table, following the trend of decreasing boiling points down group [15].

## 1.7 Chemical properties

Mercury does not react with most acids, such as dilute although oxidizing acids such as concentrated sulfuric acid and nitric acid or regain dissolve it to give sulfate, nitrate ,and chloride. Like silver, mercury atmospheric hydrogen sulfide. Mercury reacts with solid sulfur flakes, which are used in mercury spill kits to absorb mercury (spill kits also use activated carbon and powdered zinc)[16].

Mercury dissolves many metals such as gold and silver to form amalgams. Iron is an exception, and iron flasks have traditionally been used to trade mercury. Several other first row transition metals with the exception of manganese, copper and zinc are also resistant in forming amalgams. Other elements that do not readily form amalgams with mercury include platinum[17].

Mercury (Hg) is a naturally occurring element found in air, water, and soil. It is distributed throughout the environment by both natural and anthropogenic (human) processes.

The three predominant forms include:

a) Elemental mercury (with the chemical symbol of Hg).

b) Ionic mercury (also known as inorganic mercury with the chemical symbol of Hg (II) or $Hg^{2+}$) which in nature exists as Hg (II) mercuric compounds or complexes in solution.

c) Organic mercury with methyl mercury (with the chemical symbol of MeHg) being the most important, while most of the mercury in water, sediments, soil, plants and animals as found inorganic and organic forms of the element.

These forms all have different toxicities and implications for health and for measures to prevent exposure[18]. Elemental mercury is a liquid that vaporizes readily  It can stay for up to a year in the atmosphere, where it can be transported and deposited globally. It ultimately settles in the sediment of lakes, rivers or bays where it is transformed into methyl mercury, absorbed by phytoplankton, ingested by zooplankton and fish, and accumulates especially in long-lived predatory species, such as shark and swordfish[19].

**1.8 Exposure to mercury**

All humans are exposed to some level of mercury. Most people are exposed to low levels of mercury, often through chronic exposure (continuous or intermittent long term contact) However, some people are exposed to high levels of mercury, including acute exposure (exposure occurring over a short period of time, often less than a day) An example of acute exposure would be mercury exposure due to an industrial accident Factors that determine whether health effects occur and their severity include: the type of mercury concerned, the dose, the age or developmental stage of the person exposed (the fetus is most susceptible), the duration of exposure, the route of exposure (inhalation, ingestion or dermal contact).

Mercury is considered as one of the toxic and dangerous heavy metals [20], Hg can easily accumulate in the food chain and reaches to the human body through ingestion pathway and can also easily enter in to human body through inhalation and others routes and causes harmful effects on human health [21].

The metal is still widely used in many areas, including making thermometers, barometers, manometers, whitening cosmetics, and dental amalgam cultural and religious practices in some cultures, mercury is believed to chase away evil spirits when placed on the walls of houses. elsewhere, it is thought that mercury-based talismans can bring good luck. obscure religious practices involving the use of mercury are known, but the topic remains poorly documented [22].

## 1. 9 Isotopes OF Mercury

There are seven stable isotopes of mercury, with 202 Hg being the most abundant (29.86%). The longest-lived radioisotopes are 194 Hg with a half-life of 444 years, and 203 Hg with a half-life of 46.612 days. Most of the remaining radioisotopes have half-lives that are less than a day. 199 Hg and 201 Hg are the most often studied NMR-active nuclei, having spins of 1⁄2 and 3⁄2 respectively[16].

## 1.10 Mercury releases

Natural: volcanic activity, weathering of rocks, water movements, biological processes.

Human activities: combustion of fossil fuels (specially coal), electricity-generating power stations, gold and mercury mining, manufacture of cement, pesticides, chlorine, caustic soda, mirrors and medical equipment, industrial leaks, dentistry, waste and corpse incineration.

Remobilization of historic sources: mercury in soil, sediment, water, landfill, waste. Industrial use of mercury can result in different patterns of human exposures, including: Occupational exposure of workers in direct contact with either forms of mercury in their workplace. In these cases, assessment of workers' exposure to mercury can be addressed following the guidelines described earlier.

exposure of populations living near industrial settlements and impacted by releases to air or water and disposal of wastes (effluents, refuses, and landfills). For example, exposures can occur due to mercury releases from mercury-cell chlor-alkali plants. Such releases can lead to elevated mercury exposures for local communities. Therefore, local in depth assessment could be considered a priority and evaluated following the guidelines described in this document [23].

Recently, the issue of mercury toxicity according to the mercury exposure level, health effects as well as the determination of what mercury levels affect health are in the spotlight and under active discussion. Evaluating the health effects and Biomarker of mercury exposure and establishing diagnosis and treatment standards are very difficult.

# Chapter two

## Literature Review

Many African countries are going through a phase of difficult economic conditions and a high rate of unemployment and poverty in their communities. Over the years artisanal gold mining has been a source of income generation of many communities.

A recent boom in mining is stirring in different parts of the continent where the prospect of mineral resources has already been announced. This is encouraged by governmental authorities and large mining companies, so as to fill the gap in the economy deficit and involve the unemployed. In some areas people holding essential jobs are leaving, attracted by the gold glitter and wealth [24].

In recent years after referendum of Southern Sudan, most of the petroleum income was lost in Sudan, as a result nearly millions of Sudanese were forced to work in artisanal gold mining especially in River Nile State, using traditional means for extracting the gold from ores. This study was done to evaluate the occupational exposure for mercury among these miners.


**Figure (2.1): Rive Nile State**

## 2.1 Artisanal and Small-Scale Gold Mining (ASGM)

It is an informal economic activity. Most ASGM process of extracting gold ore from the ground in the absence of land rights, mining license, exploration or mining mineral exploration permit or any legitimate document that allows the operation. Its haphazard nature, location close to and dependence on water have negative effects on the physical, chemical and biological composition of water. The socio-economic benefits of small scale mining, which include employment and income generation, are seriously outweighed by devastating environmental costs and impacts.

ASGM covers a broad spectrum of activities which depend on size of work force, timing, methods used to carry out the operations and whether operations are legal, illegal, formal or informal. The mining is done mainly by poverty driven rural individuals, groups, families or cooperatives with minimal or mechanization, knowledge or technology in mining and mining safety. It is commonly associated with informal, unregulated, unregistered, unlicensed, undercapitalized and under-equipped mining operations [25]. Traditional mining artisanal scale mining is defined as an activity practiced by utilizing local traditional means within the specified area.

## 2.2 Mercury Problem in Artisanal Gold Mining

Mercury-based artisanal and small-scale gold mining (ASGM)causes more mercury pollution than any other human activity [26]. In this practice, mercury metal is used to extract gold from ore as a stable amalgam. The amalgam is then heated to evaporate the mercury and isolate the gold. While mercury amalgamation has been used for thousands of years to mine gold and silver[27] ,it is unfortunately still a widespread technique in present day, artisanal gold mining. Mercury is abundant and inexpensive ,sourced through a variety of industrial supply chains or mined directly from cinnabar, making  are daily available tool for mining gold[28]. It is estimated that between410 and 1400 tones of mercury are emitted through ASGM each year , accounting for 37% of global mercury emissions.[29]Driven by rising prices in gold (approximately 40,000 US  D k) for most of 2017 [30] , ASGM is wide spread ,with an estimated 10 to 19 million miners working primarily in Asia, Africa and South America As many as mining operations [31]. These miners typically live in improve risked cases, few other opportunities for employment exist in these regions and ASGM is therefore a critical way to sustain their livelihood [32]. These mining activities largely take place in the so-called "informal" economy in which participants operate unlicensed or without legal authorization a reason why effective regulation of mercury emissions is extraordinarily difficult[33]. Never the les ,these artisanal miners contribute substantially to the local and world's gold So while each individual mining operation may be relatively small, the practice is widespread. Because of the extraordinary amounts of mercury handled directly by the miners and released into the environment, the burden to human health is staggering [34]. Mercury vapor inhaled by miners results in impaired cognitive function, neurological damage, kidney damage and several other health problems[35]. In some cases, amalgams are processed near the home or in gold shops in villages or cities, so the mercury vapor generated in the process affects non-miners living in these areas For children and fetuses, exposure to mercury pollution is especially dangerous as it increases the likelihood of physical deformities, neurological damage and lower IQ[36]. These risks of mercury exposure are also compounded by the high levels of mercury that accumulate in fish and other food supplies in ASGM communities [ 37] .

The mercury problem in ASGM is a growing crisis in environmental and human well-being Rightfully, the issue has garnered attention in both the scientific[38] and general news media as ASGM becomes more prevalent and its effects more visible The damage to cognitive and neurological function of the miners and the physical and mental disabilities prevalent in children near ASGM communities are startlingly clear in these reports[39] Furthermore, the wider damage to the environment and the transport of high levels of mercury to sites beyond the mine have in some cases, led to national conflict and military intervention. The time to address this problem is now. On August 16th 2017, the Minamata Convention on Mercury was ratified by more than 50 parties to the treaty [40] This milestone brought into force the most comprehensive effort to control the trade, use and emissions of mercury. As ASGM is the largest source of mercury pollution worldwide, reforming this sector is a priority of the Minamata Convention Accordingly, the convention requires signatories to “take steps to reduce, and where feasible eliminate ,the use of mercury and the emissions and releases to the environment of mercury from, such mining and processing .There are also specific provisions for member nations to help educate miners and promote research into sustainable, mercury-free mining[41] In the accompanying Annex of the Minamata Convention, further actions are prescribed that include the elimination of four especially problematic activities: whole ore amalgamation, open heating of amalgams, heating amalgams in residential areas, and the use of cyanide to extract gold from mercury-rich tailings. Because thes goals will likely require advances in environmental chemistry and innovative extractive technologies, it is worthwhile to consider how the chemistry community might contribute to these global initiatives.

## 2.3 Mercury Emissions from Artisanal and Small- Scale Gold Mining

In ASGM, the amalgamation process, tailings processing, and gold recovery from the amalgam result in substantial release of mercury into the environment. By some estimates, release of mercury from ASGM exceeds  million kg each year [42]. This level of mercury pollution may exceed the combined emissions of coal combustion, cement production, chlor-alkali plant operation, and large-scale industrial mining and metallurgy It is therefore important to look at each stage of common ASGM practices to identify how mercury is released into the environment and mitigate harm. The primary sources of these emissions are from tailings discharge to land and water and mercury gas emissions during amalgam roasting. In the amalgamation process, substantial amounts of mercury can be lost in the tailings. In particular, milling ore and mercury in trommels can result in the formation of tiny mercury droplets that become finely dispersed in the tailings. This "mercury flour" is especially and transported far from the mining site In some cases, mercury-rich tailings can travel in rivers hundreds of kilometers from the mine. The floured mercury is also difficult to recover because it does not coalesce efficiently

## 2.4 Biological markers

Exposures can be estimated by measuring pollutant levels in various body tissues (such as hair, blood, cord, urine, human milk and nails). These measurements, also known as biological markers (or biomarkers), are useful tools for human exposure assessment. They are sensitive indices of an individual's exposure to mercury, providing a measure of the internal dose, which can be used to evaluate the likelihood of adverse health effects and improve clinical diagnoses. These biomarkers are useful as surveillance tools for monitoring mercury exposure in individuals and populations. There is a well-established relationship between several biomarkers of mercury exposure and adverse health effects.

## 2.5 Blood Mercury Concentration

Blood mercury concentrations can be determined by a variety of analytical techniques. Often blood samples are digested with high purity mineral acids and oxidants prior to instrumental analysis. Sample preparation and digestion procedures play an important role in blood sample analysis as the sample matrix can interfere with analysis and lead to inaccurate results.

Blood mercury concentrations rapidly increase immediately after or during brief exposure. Therefore, the measurement also needs to take place right after the exposure  However, in cases of those who have been chronically exposed to mercury, blood mercury concentration levels maintained a high level even when the exposure has ceased, due to the heavy burden of mercury on the body [43]. In the meantime, the concentration level of methyl mercury which accounts for the largest share in the blood is known to be linked with the amount of mercury we are exposed to daily, according to the equation Furthermore, although the concentration level of methyl mercury in red blood cells is high in acute poisoning, it varies widely in chronic intoxication. The mercury concentration in whole blood is usually lower than 10 μg/L, but the value of 20 μg/L or below is considered normal. The blood mercury concentration can rise to 35 μg/L after long-term exposure to mercury vapor [44].

study was conducted in Abuhamed mining area in Sudan ,The aim of the study was to evaluate serum mercury levels and to assess lung functions in artisanal gold miners. The study included 123 subjects, of them 83 were working in the gold mining area, beside 50 healthy volunteers from Khartoum State, as control group. Serum mercury was measured by direct mercury analyzer (DMA-80). Lung function tests were done with a portable spectrometer. Data were analyzed using IBM SPSS Statistics version 20. The study observed significant increase in serum mercury levels in the gold miners, when compared with control group (24.9 ± 32.24μg/l) versus (1.40 ± 0.94μg/l) with P value (0.000). The mean forced expiratory volume in the first second (FEV1) in the gold miners was (3.24 ± 0.57) versus (3.40 ± 0.39) in the control group, while the mean forced vital capacity (FVC) in the mercury exposed miners was (3.7 ± 0.69) versus (3.86 ± 0.60) in non-exposed control group[45] . A biomonitoring study was carried out to examine the adverse impacts of total mercury in the blood (HgB), urine (HgU) and human scalp hair (HgH) on the residents of a mining district in Colombia. Representative biological samples (scalp hair, urine and blood) were collected from volunteered participants (*n* = 63) to estimate the exposure levels of THg using a Direct mercury analyzer ,The an average geometric mean of THg concentrations in the blood of were(10.05 μg/L) [46].

Study Mercury exposure of gold mining workers in the northwest of Iran In this study, blood and urine concentrations of mercury were determined using hydride generation atomic absorption spectrophotometer (HGAAS) in sixteen gold miners with neuropsychiatric symptoms. The patients treated with two chelating agents, dimercaprol and Dpenicillamine. The mean serum mercury levels before and after chelation therapy were 208.14 μg/L-1 and 10.50 μg/L-1, respectively. The mean urinary mercury levels before and after chelation therapy were 134.70 μg/L-1 and 17.23 μg/L-1, respectively. The results of this study showed that there are significant differences between concentration of blood and urine mercury before and after intervention (*p*<0.005). There were no significant differences between in the biochemistry parameters of patients before and after treatment study Mercury exposure of gold mining workers in the northwest of Iran concluded that dermal absorption of elemental mercury is limited by estimating that dermal absorption only contributed2.6% of the absorbed mercury following exposure Approximately to elemental mercury vapor in the air; the other97.4% occurred through inhalation15. The result of this study showed no significant relationship between amalgam filing and mercury concentration, which is the same as Hursh et al.15 that there is no relationship between mercury concentrations in lower parts of the brain and the number of amalgam fillings in the mouth [47] .

**2.6 Examples of biomonitoring studies :**

Mercury exposures of many populations have been monitored by measuring mercury in blood.

**Table (2.1) : Studies of biomarkers of exposure to mercury [48]**

| Country | Matrix | Population | Concentration of total mercury |
|---|---|---|---|
| Spain | Blood | Representative | 11-22 ng/g |
| Sweden | Blood | Pregnant women | 1.3 µg/l |
| USA | Blood | Women aged 16-49 yrs | 1.2 µg/l |
| USA | Blood | Representative of high end fish consumers | 14.5 µg/l |
| Korea | Blood | Adults | 4.28 µg/l |

# Chapter Three

# Material And Methods

## Material

### Reagents

All analytical grade reagents were purchased from Merck Darmstadt. Deionized (18.2MΩcm_1) water was used throughout the experiments, obtained from lab water purification system (USF ELGA maxima HPLC made in UK).

## 3.1 METHODS

### 3.1.1 Study Design

An analytical cross-sectional observational study.

### 3.1.2 Study Area

The study was carried in Altwahen gold mining area, located 12 km from

Abu hamad city, in Nile river state Sudansituated in Northern, Sudan, its geographical coordinates are 19° 32' 0" North, 33° 19' 0" East. .

### 3.1.3 Study Population

The traditional gold miners included in this study, have been in the mining area in the desert, for more than 6successive months. They were living in small camps nearby working area, which included wells, stone mills, washing and molding. The washing performed in water pools where gold was mixed with mercury and then the mixture heated was small metal pans directly in the air. Bare hands, feet and faces were seen in all the processes.

All participants are from Abu hamad gold mining area were included gold miners, who worked in ,and non-miner from Atbara city as control .

**3.1.4 Inclusion Criteria**

The study include all participant who completed the questionnaire and gave blood sample N=( 18)

Working in the field of traditional gold mining for not less than 6 months

3.1.5 **Sample size**

18 samples were taken from different workers covering all activities and practices in the mining area: 18 traditional gold miners: mercury burning (4 samples) ,Miller (4 samples ) ,mercury washing (4samples)

werkers in Shops in mining areas (6samples) , A sample normal healthy control, from Atbara not been in mining areas.

**3.1.6 Data Collection**

The questionnaire designed as WHO guideline using EPI INFO software. Interview questionnaire was conducted with all the participants. .

**3.1.7 Samples collection**

5-mL of blood samples collected plastic containers. Blood specimens were collected from the all the subjects under study in sterile conditions into sterile plain containers and the serum was separated by centrifugation into another plain container, and then stored at -70$^{\circ}$ C till the time of analysis.

**3.2.1 Determination of Mercury in Whole Blood**

One mL of serum blood was mixed with 5 ml of nitric acid and kept in a water bath at a temperature of 60 C° for 12-14 hour after the digestion process is complete, the samples was diluted by deionized water to mark 25 ml in volumetric flask and Analyzed by Inductive Coupled Plazma Emission (ICPE9000 ) .

### 3.2.3 Preparation Of Standards

The standard solutions of mercury were prepared by serial dilution from known standard stock solutions of 1000 mg/L. A calibration curve was prepared and then the analysis of the samples for the mercury were done.

### *3.2.4 Instrumentation*

**Inductive Coupled Plazma Emission Instrument (ICPE9000)**

ICP emission spectrometers are analytical instruments used in a broad range of fields. They feature are: high ppb level detection ability, broad 5-6 digit analysis concentration ranges, and batch analysis of multiple elements. Recent wider usage has resulted in an increased demand for shorter analysis times and improved,high-matrix sample detection,samples can be evaluated in a number of ways,The Assistant Function automatically,carries out wavelength selection for measured elements and interference correction,Simple and accurate measurement is possible even with hard-to-measure high-matrix samples.


**Figure (3.1 ): Inductive Coupled  Plazma Emission Spctrometer**

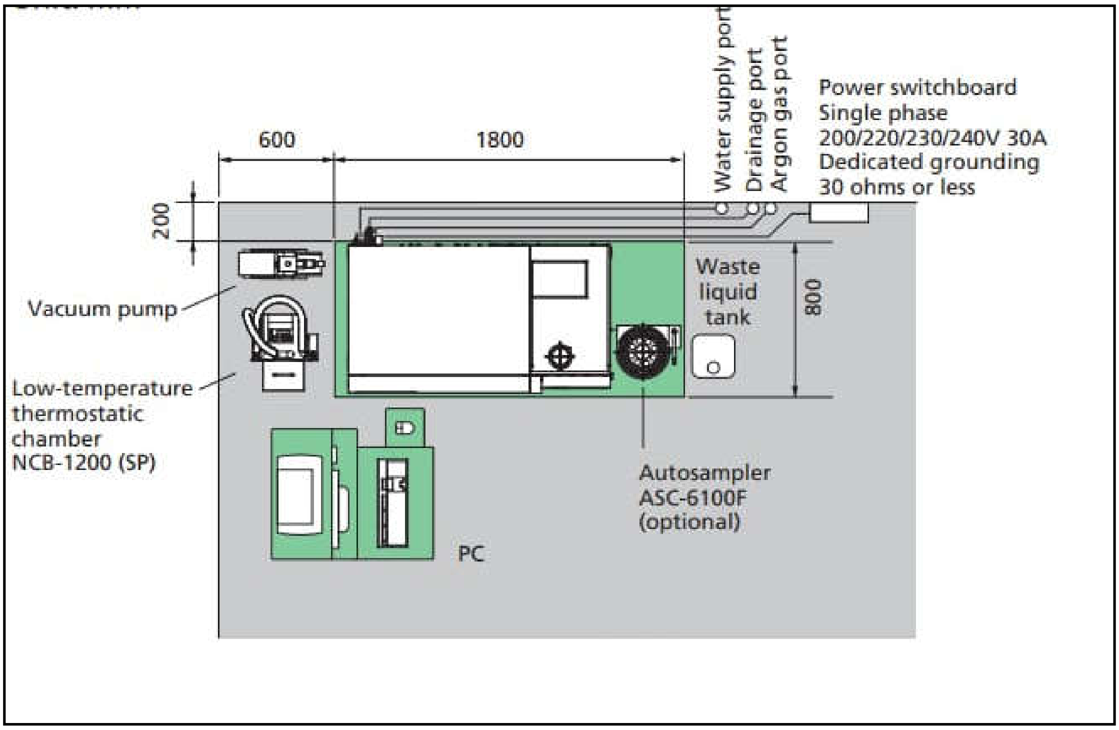


**Figure (3.2): Inductive Coupled Plazma Emission Spectrometer diagram (ICPE9000)**

**Figure (3.3): Open Dish Mercury Washing Taken from Study Area**

**Figure (3.3) mercury burning Taken from Study Area**

**Figure (3.5) Wet Mills Taken from Study Area**

**Figure (3.6) Separate the serum by using centrifugation Taken in Abuhamad hospital**

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**Figure (3.7): Mills for Powdering Stones Taken from Stdy Area**

# Chapter Four

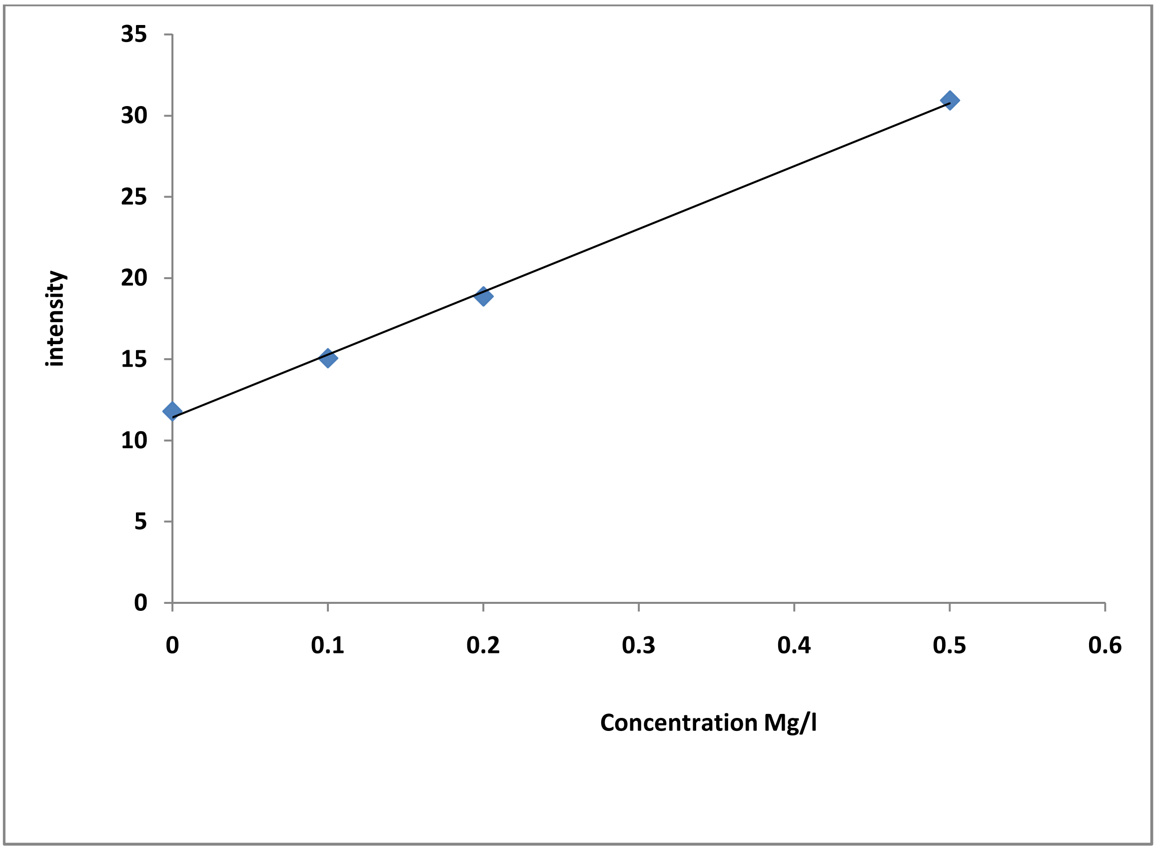
## Results and Dissection

From the stanard solution of mercury (1000 mg/l) for ICPE analysis the obtained results are tabulated in table (4.1). The calibration curve showed a good lineraty with a high regression coefficient this range covered disolved concenteration of mercury in blood worker in their …. activtis in study area .

($R^2$=0.998) within the range of the studied concentrations, Figure(4.1).

**Table (4.1 ) : Standard Samples for Calibration Curve**

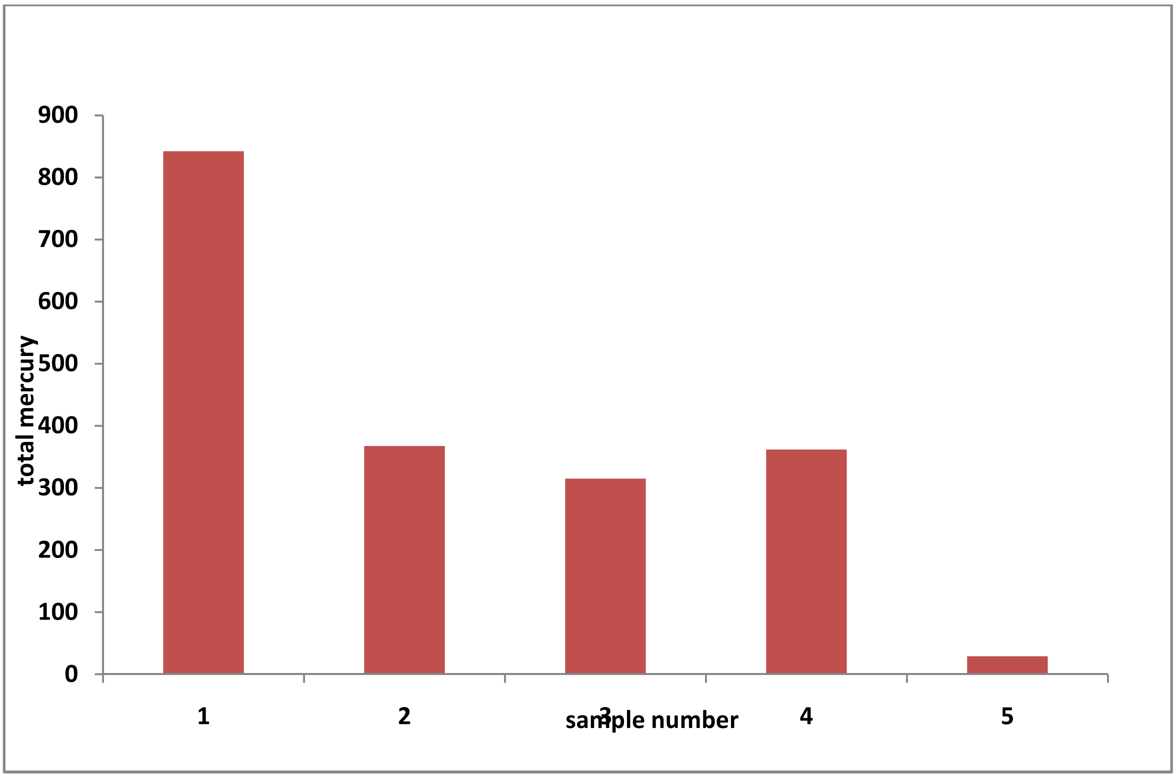
| Concentration m/l | INTENSITY |
|---|---|
| 0.000 | 11.789 |
| 0.1000 | 15.059 |
| 0.2000 | 18.857 |
| 0.5000 | 30.920 |




**Figure(4.1):Calibration Curve for stander Mercury Level in Blood Sample (ICPE9000)**

**Table (4.2): Total mercury Concentration μg/l , in blood sample from working in burning sector**

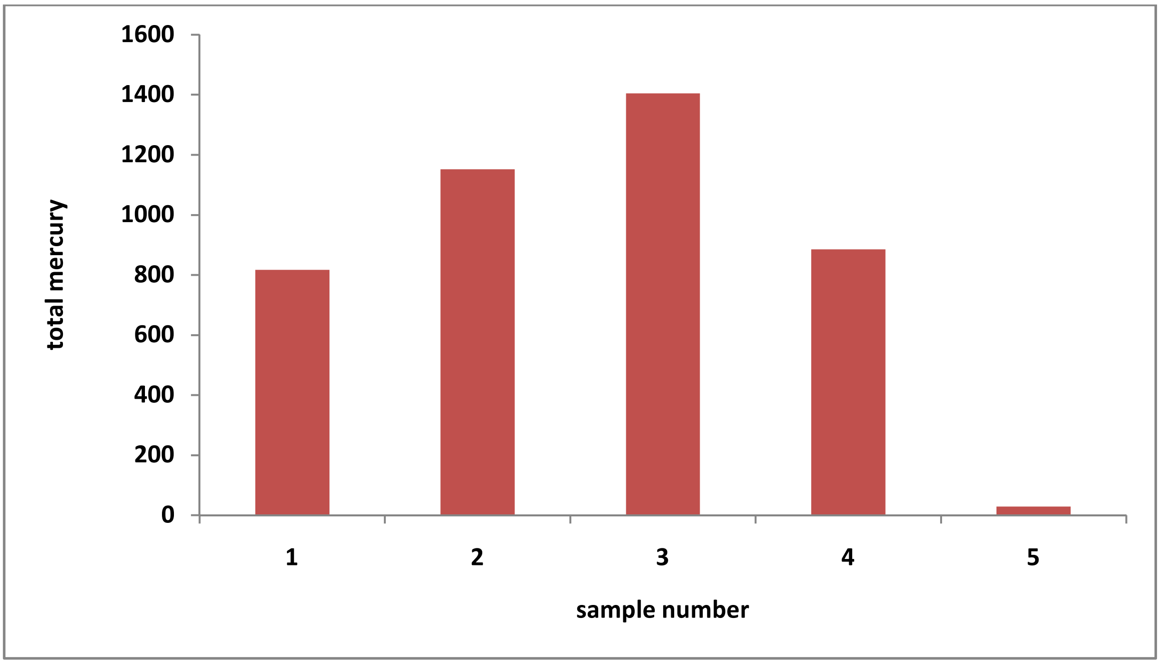
| Sample No | Quant Average mg/L | Total mercury μg/l | INTENSITY |
|---|---|---|---|
| 1 | 0.0337 | 842.5 | 13.383 |
| 2 | 0.0147 | 367.5 | 11.629 |
| 3 | 0.0126 | 315 | 11.545 |
| 4 | 0.0145 | 362 | 11.621 |
| Reference | 0.00116 | 29 | 11.092 |




**Figure(4.2): Total mercury Concentration µg/l , in blood sample from working in burning sector**

**able (4.3): mercury µg/l in blood samples ( mills)**

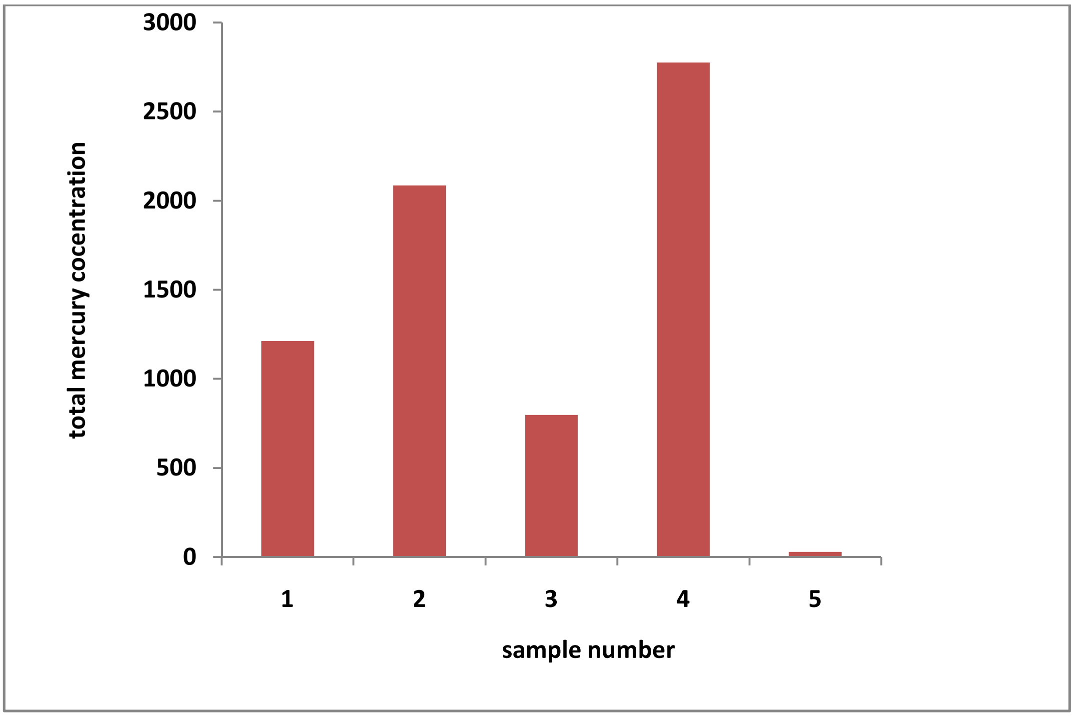
| Number | Quant Average mg/L | Total murcery µg/l | INTENSITY |
|---|---|---|---|
| 1 | 0.0327 | 817.5 | 12.343 |
| 2 | 0.0461 | 1152 | 12.874 |
| 3 | 0.0562 | 1405 | 13.375 |
| 4 | 0.0354 | 885 | 13.450 |
| Reference | 0.00116 | 29 | 11.092 |




**Figure(4.3): mercury µg/l in blood samples( mills)**

**Table(4.4): Total Mercury µg/l in Blood Samples ( washing )**

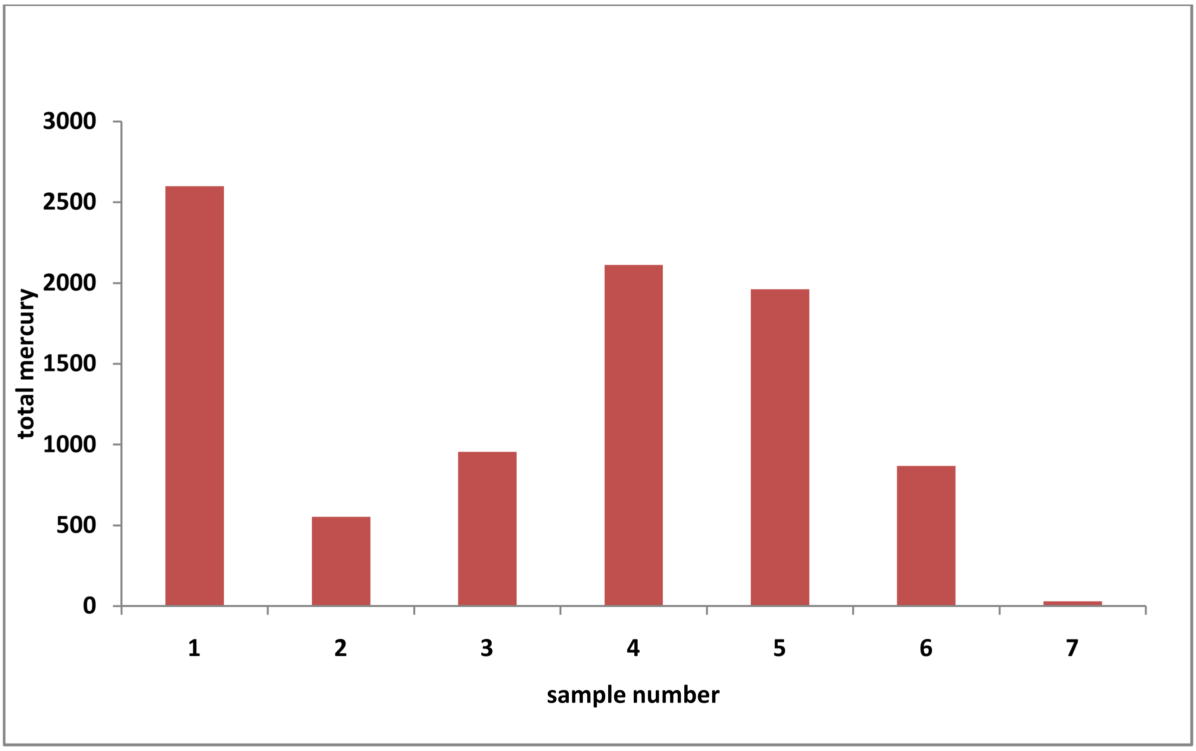
| Number | Quant Average mg/L | Total mercury µg/l | INTENSITY |
|---|---|---|---|
| 1 | 0.0485 | 1212 | 12.969 |
| 2 | 0.0834 | 2085 | 14.357 |
| 3 | 0.0319 | 797.5 | 12.311 |
| 4 | 0.111 | 2775 | 15.449 |
| Reference | 0.00116 | 29 | 11.092 |




**Figure(4.4) : Total Mercury µg/l in Blood Samples ( washing )**

**Table(4.5): Total Mercury µg/l in Blood Samples( worker in shops )**

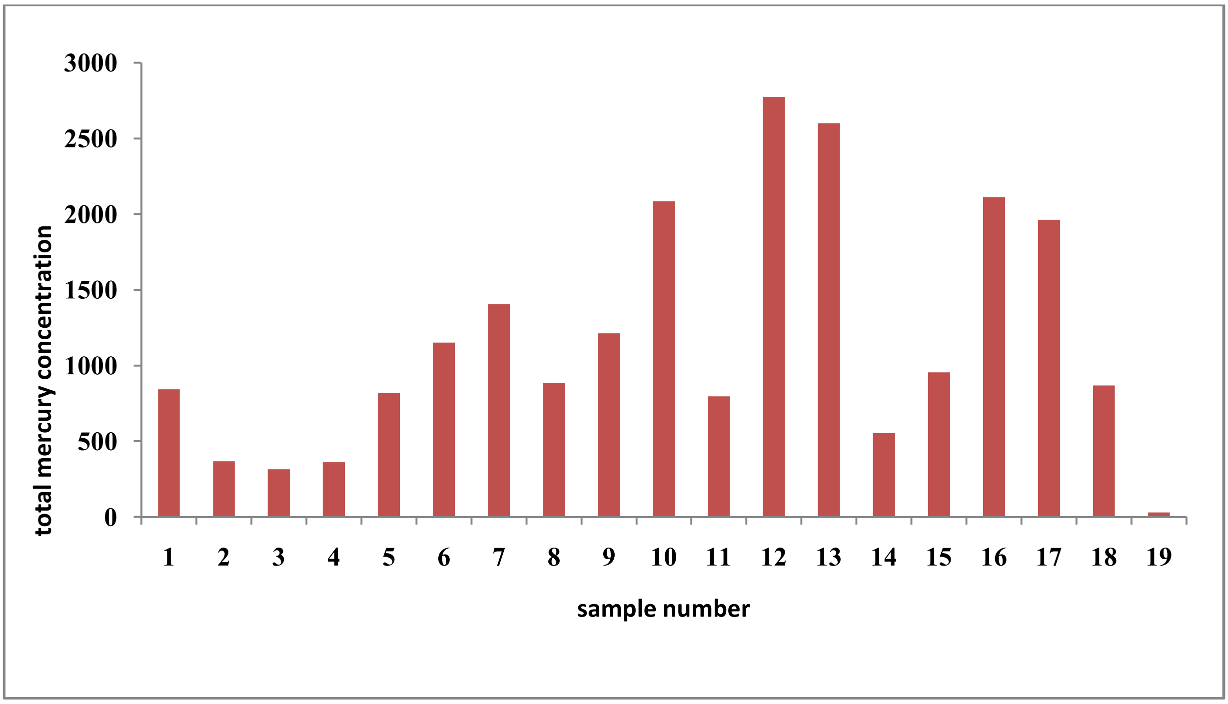
| Number | Quant Average mg/L | Total Mercury µg/l | INTENSITY |
|---|---|---|---|
| 1 | 0.104 | 2600 | 15.171 |
| 2 | 0.0221 | 552.5 | 11.918 |
| 3 | 0.0382 | 955 | 12.561 |
| 4 | 0.0845 | 2112 | 14.397 |
| 5 | 0.0785 | 1962 | 14.159 |
| 6 | 0.0347 | 867.5 | 12.422 |
| Reference | 0.00116 | 29 | 11.092 |




**Figure(4.5) : Total Mercury μg/l in Blood Samples Worker in shops**

**Table(4.6): Total mercury µg/l in all samples**

| Sample NO | Quant Average mg/L | Total murcery µg/l | INTENSITY |
|---|---|---|---|
| 1 | 0.0337 | 842.5 | 13.383 |
| 2 | 0.0147 | 367.5 | 11.629 |
| 3 | 0.0126 | 315 | 11.545 |
| 4 | 0.0145 | 362 | 11.621 |
| 5 | 0.0327 | 817.5 | 12.343 |
| 6 | 0.0461 | 1152 | 12.874 |
| 7 | 0.0562 | 1405 | 13.375 |
| 8 | 0.0354 | 885 | 13.450 |
| 9 | 0.0485 | 1212 | 12.969 |
| 10 | 0.0834 | 2085 | 14.357 |
| 11 | 0.0319 | 797.5 | 12.311 |
| 12 | 0.111 | 2775 | 15.449 |
| 13 | 0.104 | 2600 | 15.171 |
| 14 | 0.0221 | 552.5 | 11.918 |
| 15 | 0.0382 | 955 | 12.561 |
| 16 | 0.0845 | 2112 | 14.397 |
| 17 | 0.0785 | 1962 | 14.159 |
| 18 | 0.0347 | 867.5 | 12.422 |
| 19 | 0.00116 | 29 | 11.0 |




**Figure(4.6) : Total mercury µg/l in all blood samples**

**Table (4.7): Distribution of study group according to age**

| **Age** | Frequency | Percent% |
|---|---|---|
| 19-35 | 11 | 61.1 |
| 36-50 | 6 | 33.3 |
| Over 50 | 1 | 5.6 |
| Total | 18 | 100.0 |

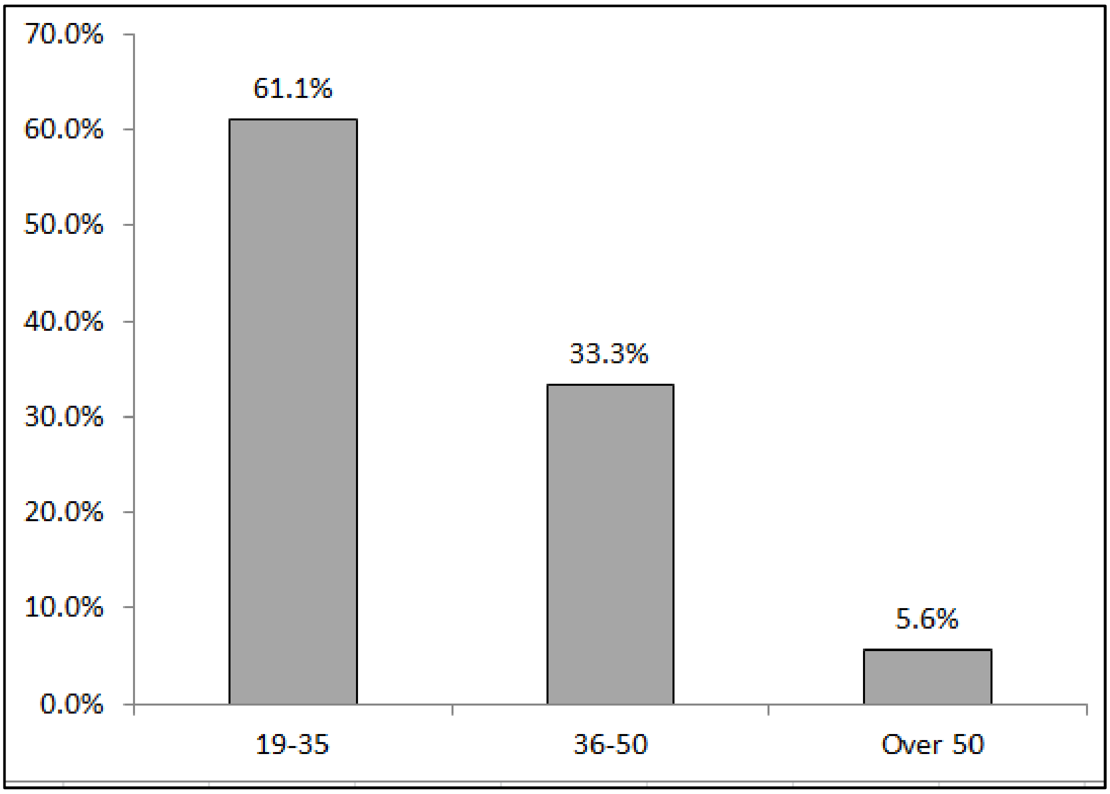



**Figure (4.7): Distribution of study group according to age**

**Table (4.8): Distribution of study group according to marital status**

| Marital Status | Frequency | Percent% |
|---|---|---|
| married | 12 | 66.7 |
| single | 6 | 33.3 |
| Total | 18 | 100.0 |

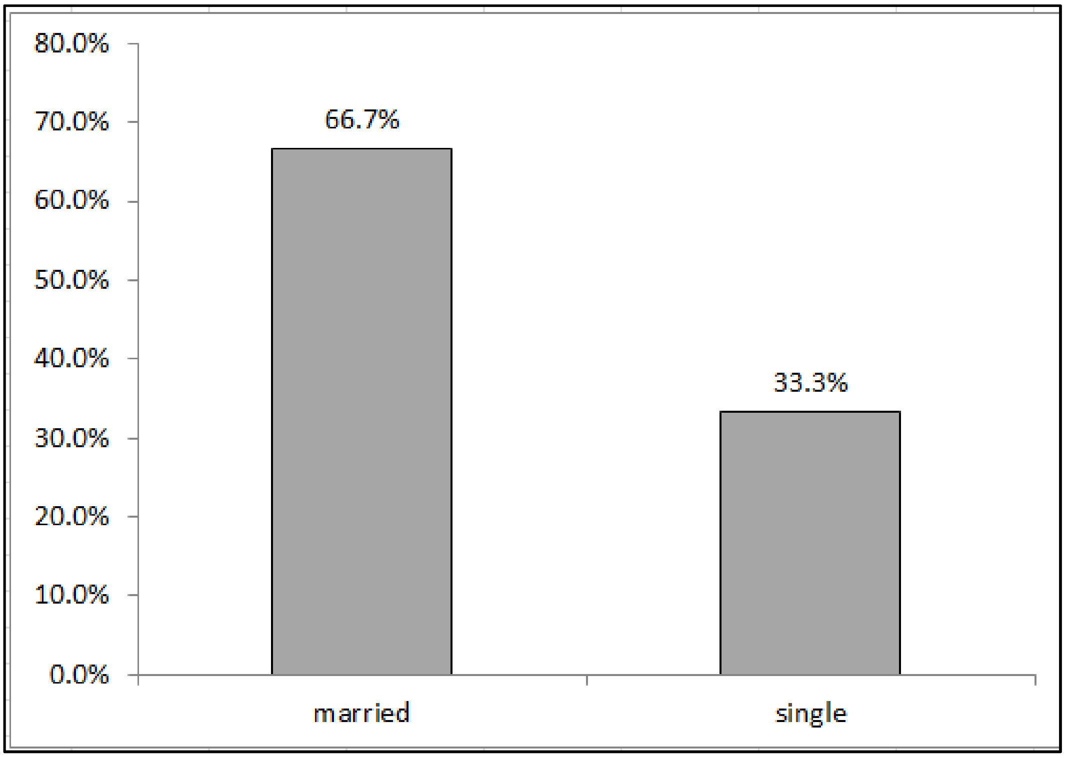



**Figure (4.8): Distribution of study group according to marital status**

**Table (4.9): Distribution of study group according to type activity**

| Type of activity | Frequency | Percent% |
|---|---|---|
| Mills | 4 | 22.2 |
| Washing | 4 | 22.2 |
| Mercury Burn | 4 | 22.2 |
| Shop | 6 | 33.3 |
| Total | 18 | 100.0 |

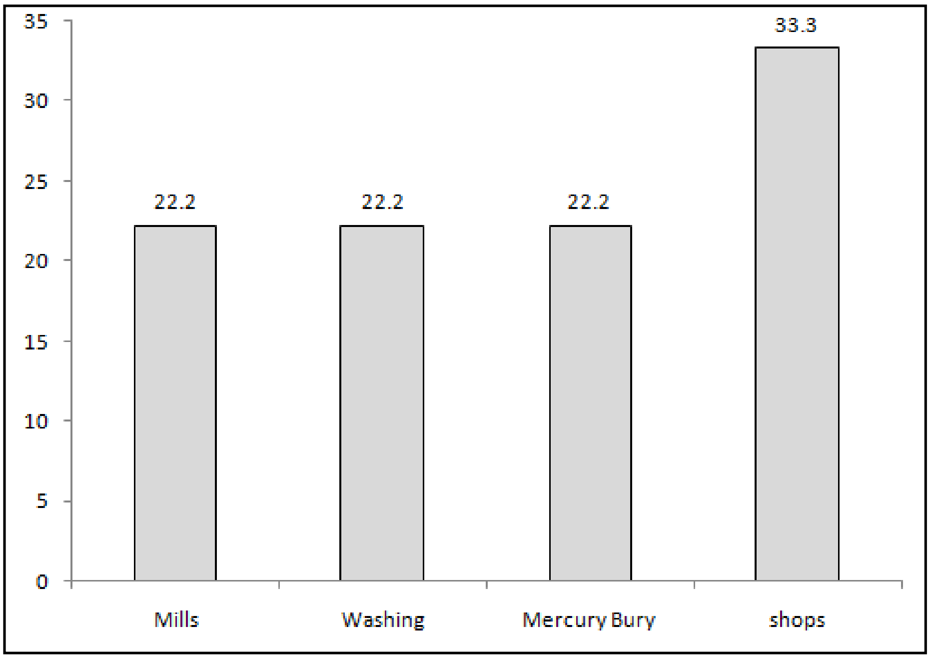
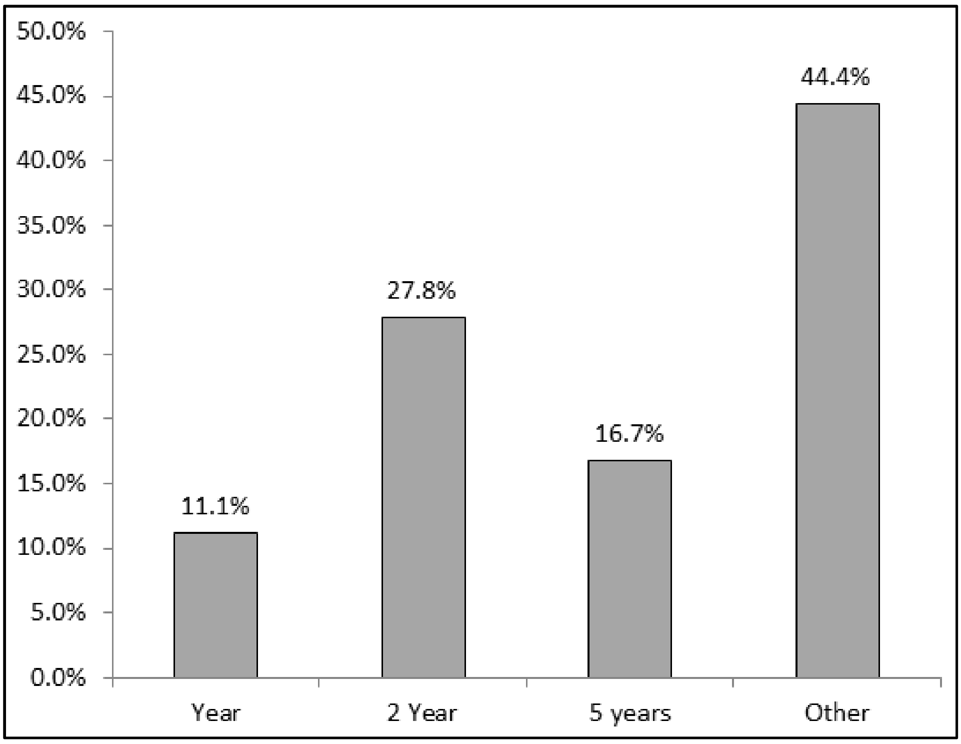



**Figure (4.9): Distribution of study group according to type of activity**

**Table(4.10): Distribution of study group according to the time period for mining work**

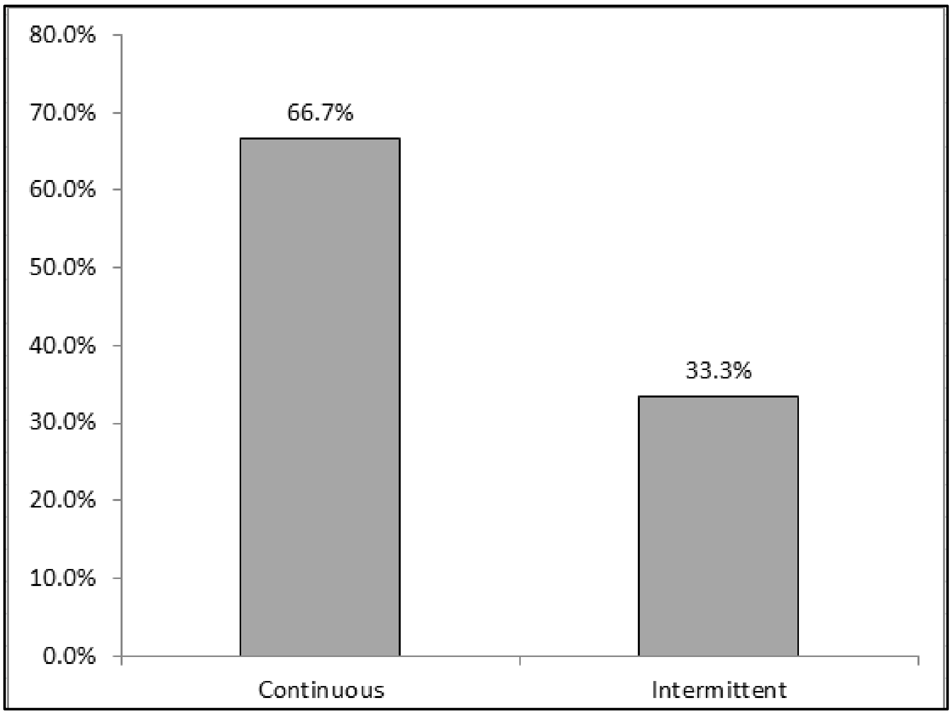
| The time period for mining work | Frequency | Percent% |
|---|---|---|
| Year | 2 | 11.1 |
| 2 Year | 5 | 27.8 |
| 5 years | 3 | 16.7 |
| Other | 8 | 44.4 |
| Total | 18 | 100.0 |




**Figure(4.10): Distribution of study group according to the time period for mining work**

**Table(4.11): Distribution of study group according tothe period of time to work**

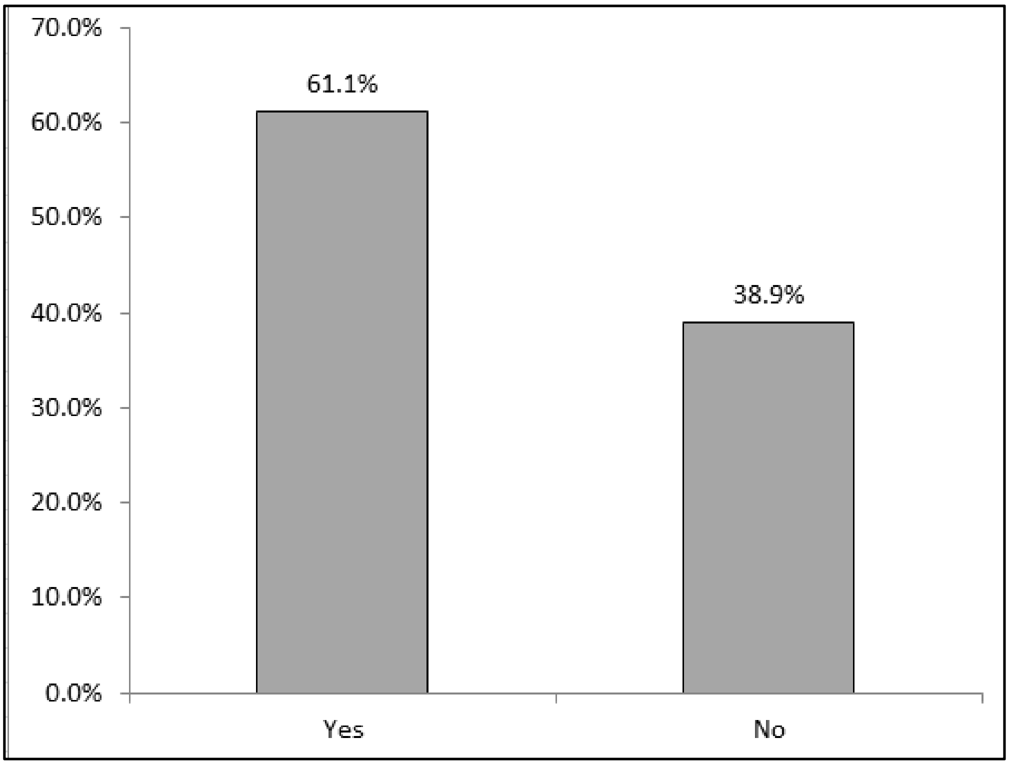
| The period of time to work | Frequency | Percent% |
|---|---|---|
| Continuous | 12 | 66.7 |
| Intermittent | 6 | 33.3 |
| Total | 18 | 100.0 |




**Figure(4.11): Distribution of study group according to the period of time to work**

**Table(4.12): Distribution of study group according contact mercury**

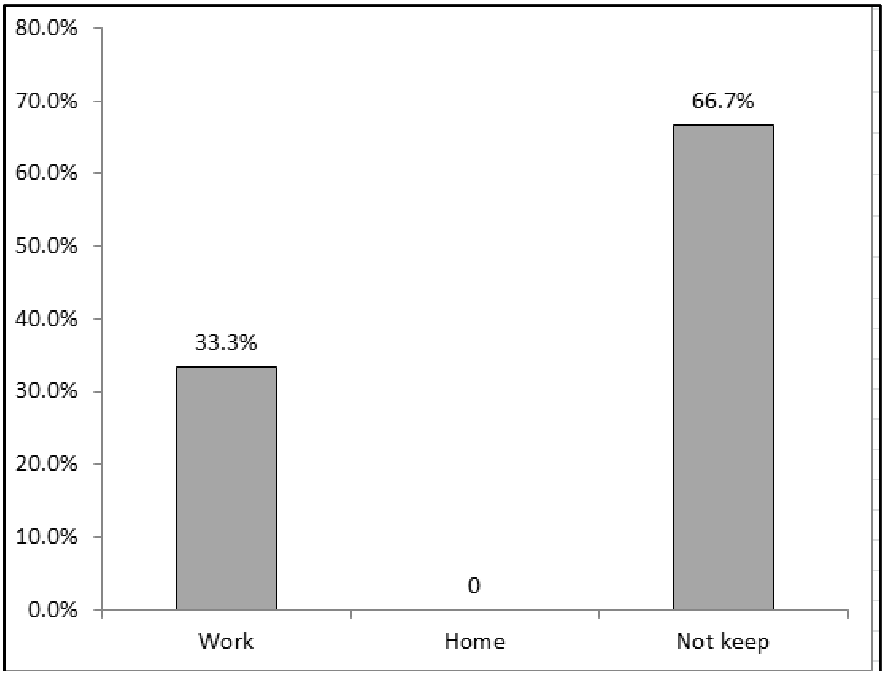
| Dealing with mercury | Frequency | Percent% |
|---|---|---|
| Yes | 11 | 61.1 |
| No | 7 | 38.9 |
| Total | 18 | 100.0 |




**Figure(4.12): Distribution of study group according to contact with contact mercury**

**Table(4.13): Distribution of study group according to mercury store**

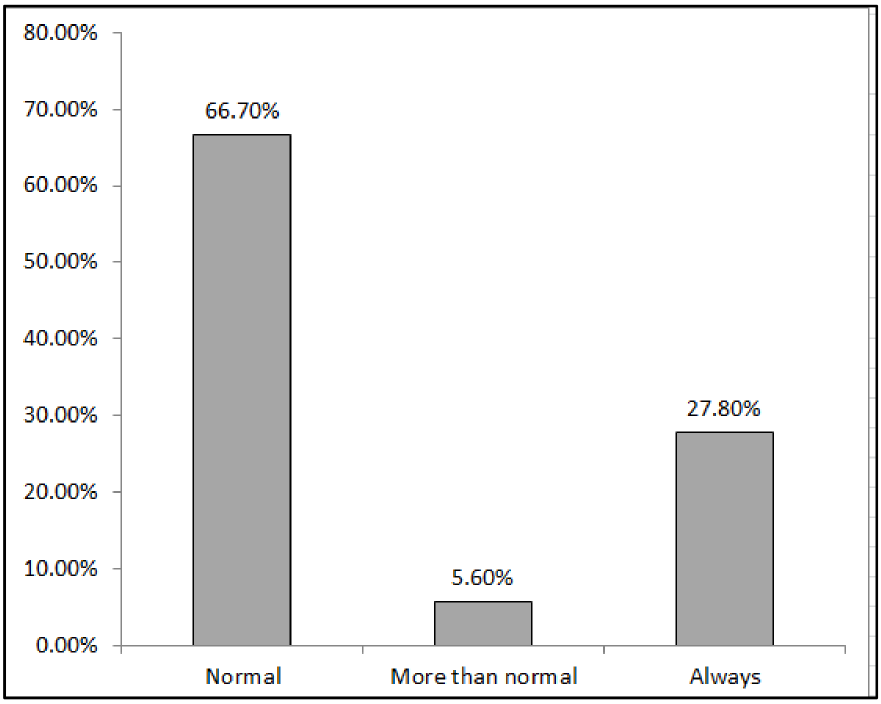
| Mercury store | Frequency | Percent% |
|---|---|---|
| Work | 6 | 33.3 |
| Home | 0 | 0 |
| Not keep | 12 | 66.7 |
| Total | 18 | 100.0 |




**Figure(4.13): Distribution of study group according to mercury store**

**Table(4.14): Distribution of study group according to feeling tired**

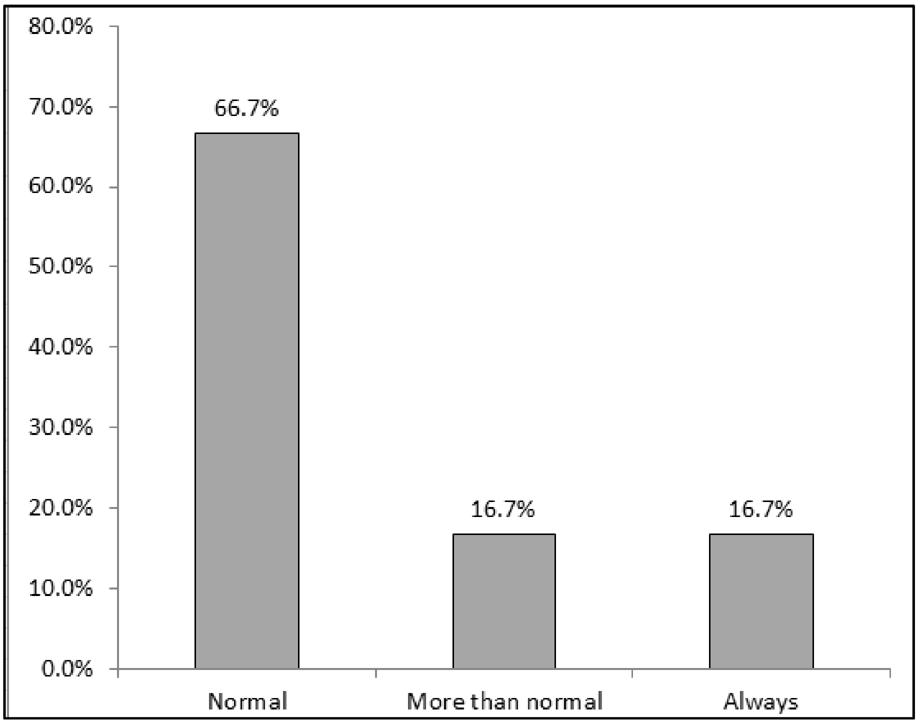
| Feeling tired and tired | Frequency | Percent% |
|---|---|---|
| Normal | 12 | 66.7 |
| More than normal | 1 | 5.6 |
| Always | 5 | 27.8 |
| Total | 18 | 100.0 |




**Figure(4.14): Distribution of study group according to feeling tired**

**Table(4.15): Distribution of study group according to feeling sleepy and drowsy**

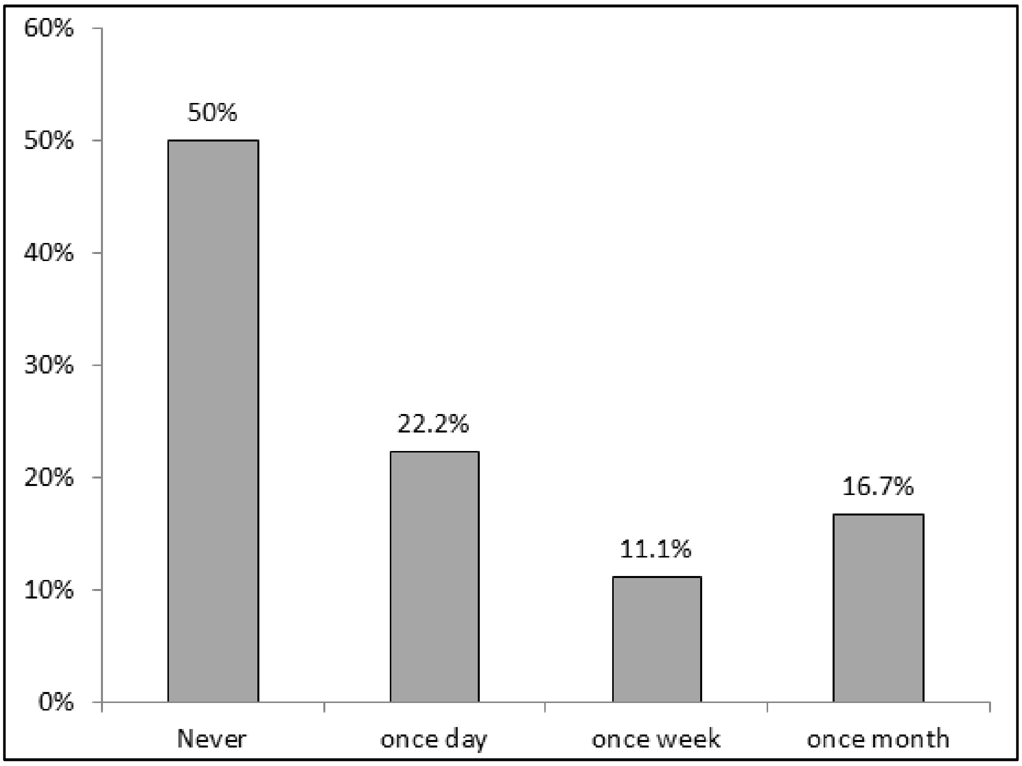
| Feeling sleepy and drowsy | Frequency | P ercent% |
|---|---|---|
| Normal | 12 | 66.7 |
| More than normal | 3 | 16.7 |
| Always | 3 | 16.7 |
| Total | 18 | 100.0 |




**Figure(4.15): Distribution of study group according to feeling sleepy and drowsy**

**Table(4.16): Distribution of study group according to palpitations**

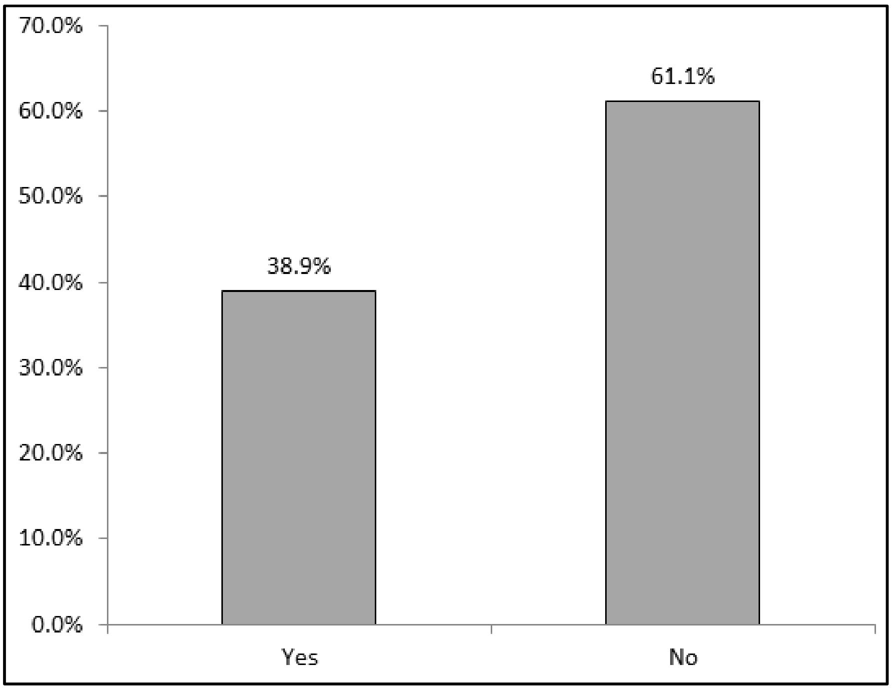
| Heart palpitations | Frequency | Percent% |
|---|---|---|
| Never | 9 | 50.0 |
| once day | 4 | 22.2 |
| once week | 2 | 11.1 |
| once month | 3 | 16.7 |
| Total | 18 | 100.0 |




**Figure(4.16): Distribution of study group according to palpitations**

**Table(4.17): Distribution of study group according to syncope attack**

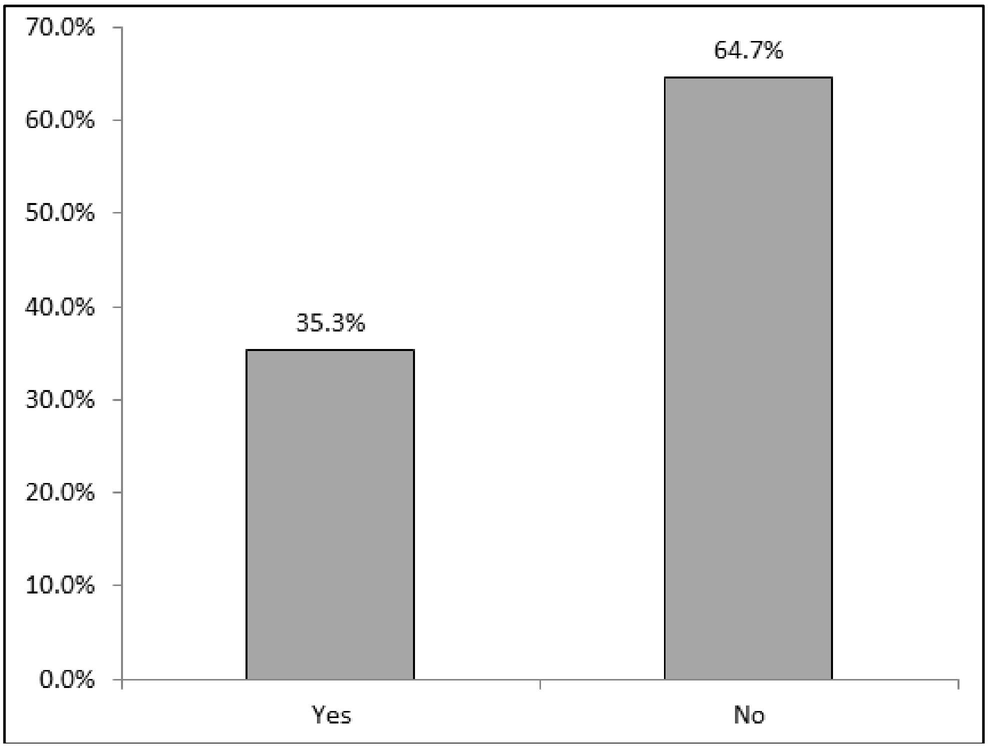
| Have you ever passed out? | Frequency | Percent% |
|---|---|---|
| Yes | 7 | 38.9 |
| No | 11 | 61.1 |
| Total | 18 | 100.0 |




**Figure(4.17): Distribution of study group according to syncope attack**

**Table(4.18): Distribution of study group according to A chronic disease:**

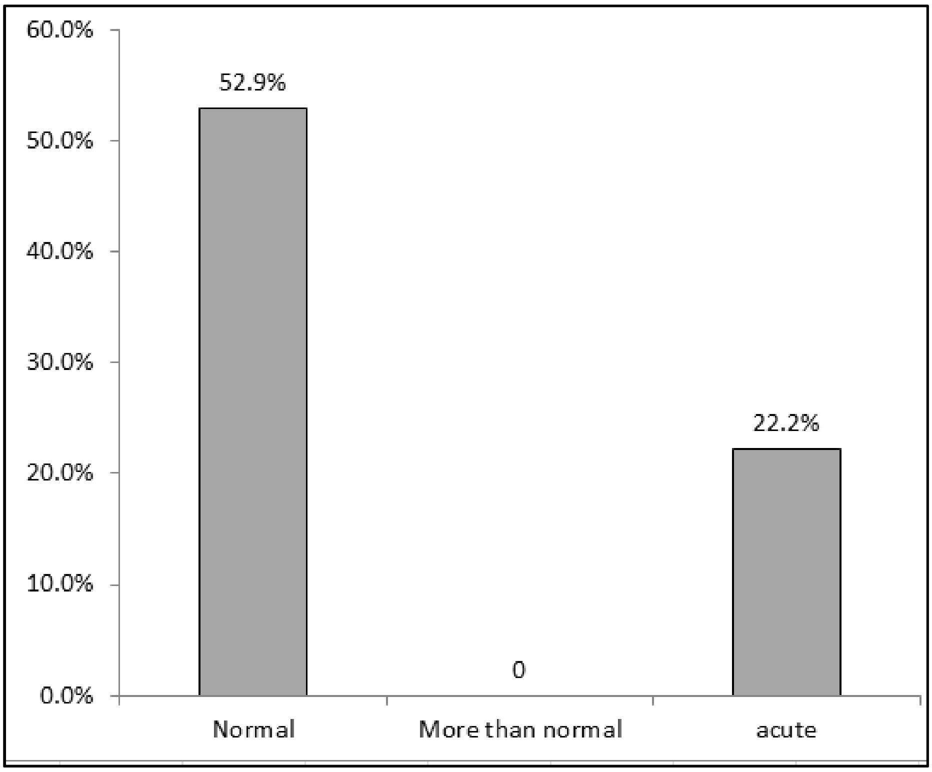
| chronic disease | Frequency | Percent% |
|---|---|---|
| Yes | 6 | 35.3 |
| No | 11 | 64.7 |
| Total | 17 | 100.0 |




**Figure(4.18): Distribution of study group according to a chronic disease**

**Table(4.19): Distribution of study group according to feeling headache**

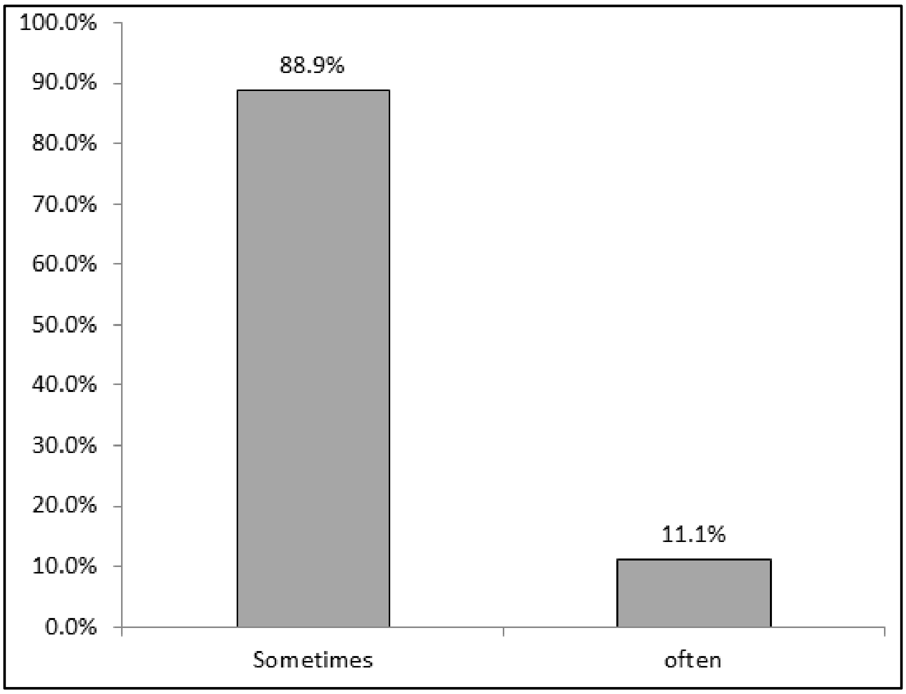
| Feeling headache | Frequency | Percent% |
|---|---|---|
| Normal | 14 | 52.9 |
| More than normal | 0 | 0 |
| acute | 4 | 22.2 |
| Total | 18 | 100.0 |




**Figure(4.19): Distribution of study group according to feeling headache**

**Table(4.20): Distribution of study group according to feeling stress and sadness**

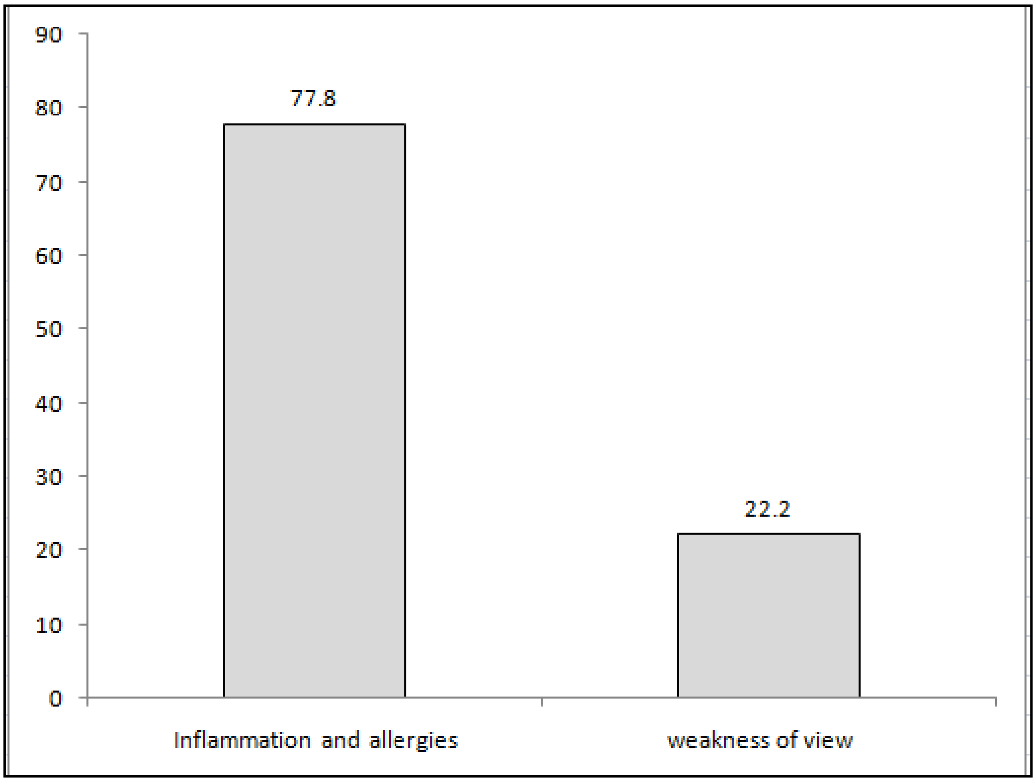
| Feeling stress and sadness | Frequency | Percent% |
|---|---|---|
| Sometimes | 16 | 88.9 |
| Often | 2 | 11.1 |
| Total | 18 | 100.0 |




**Figure(4.20): Distribution of study group according feeling stress and sadness**

**Table(4.21): Distribution of study group according to Eye problems**

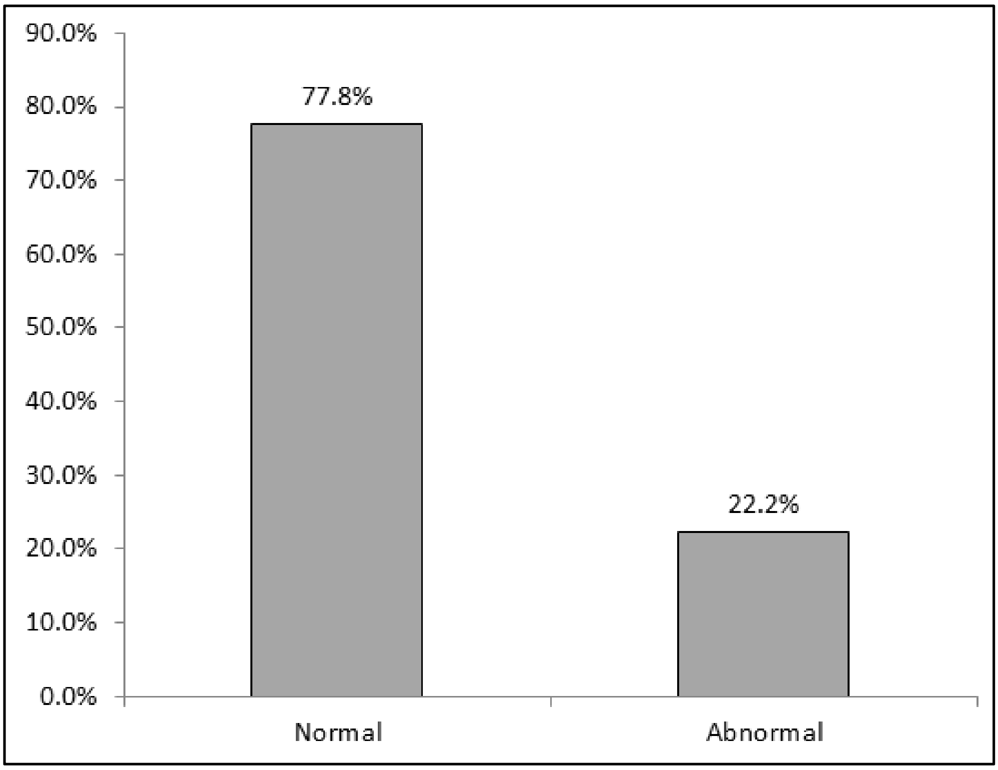
| **Eye problems** | Frequency | Percent% |
|---|---|---|
| Inflammation and allergies | 14 | 77.8 |
| weakness of view | 4 | 22.2 |
| Total | 18 | 100.0 |




**Figure(4.21): Distribution of study group according to Eye problems**

**Table(4.22):Distribution of study group according to Memory problems**

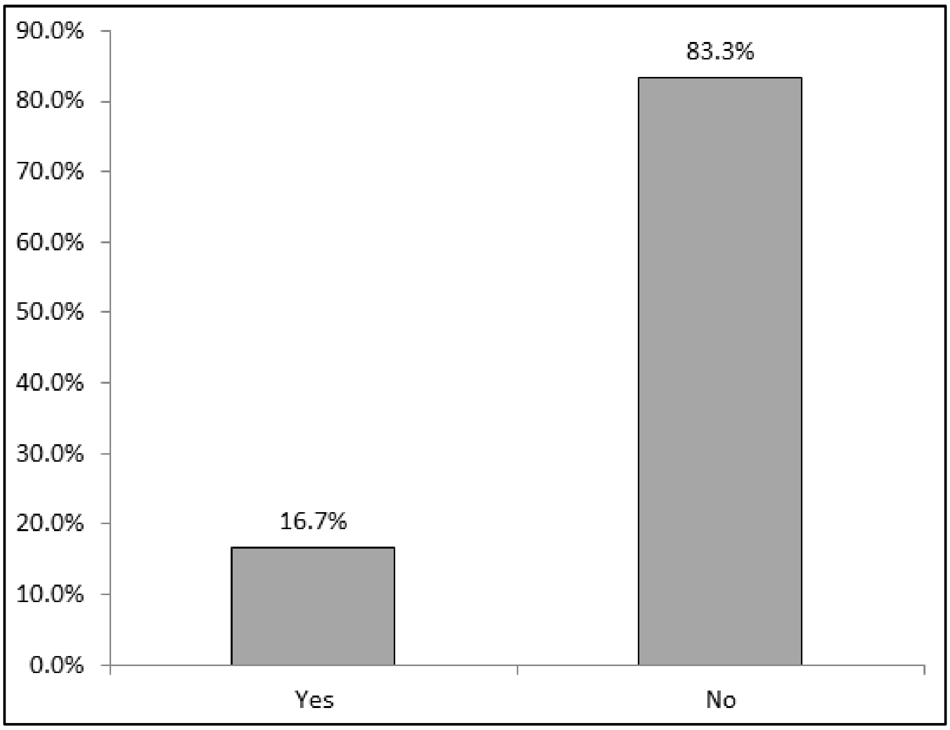
| **Memory problems** | Frequency | Percent% |
| --- | --- | --- |
| Normal | 12 | 66.7 |
| Abnormal | 6 | 33.3 |
| Total | 18 | 100.0 |




**Figure(4.22):Distribution of study group according to Memory problems**

**Table(4.23):Distribution of study group according todo you get poisoned on working days**

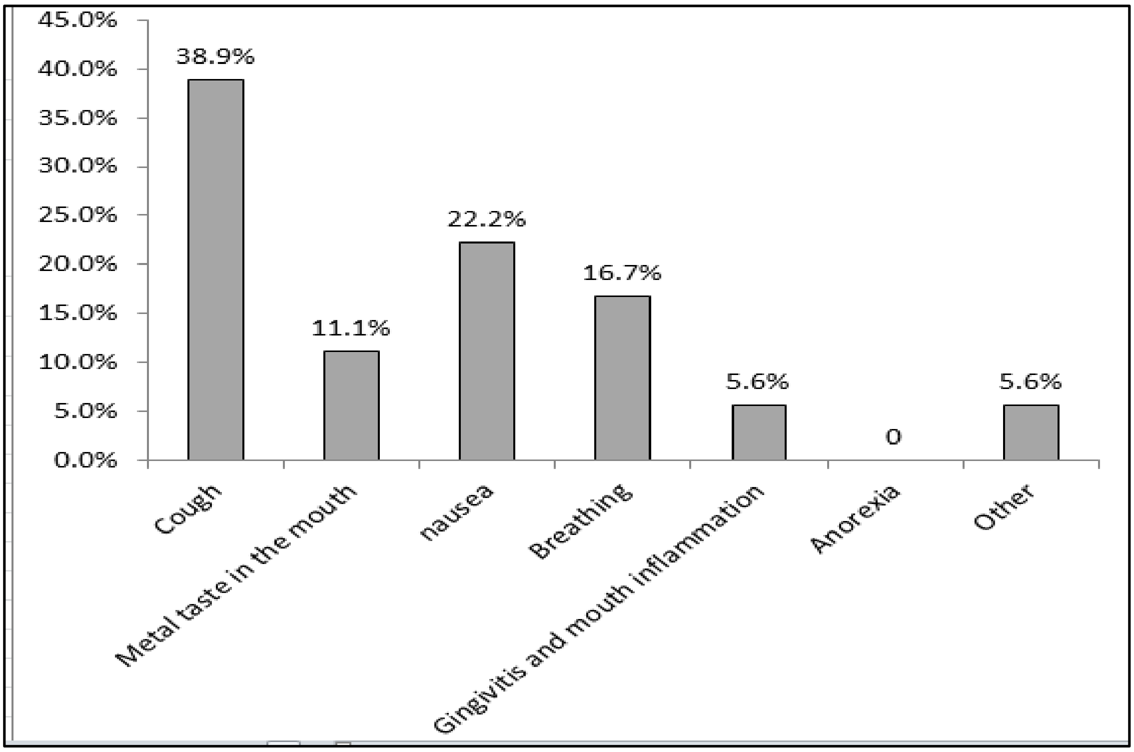
| poisoned on working days | Frequency | Percent% |
|---|---|---|
| Yes | 3 | 16.7 |
| No | 15 | 83.3 |
| Total | 18 | 100.0 |




**Figure(4.23):Distribution of study group according todo you get poisoned on working days**

**Table(4.24):Distribution of study group according to General health status**

| General health status | Frequency | Percent% |
|---|---|---|
| Cough | 7 | 38.9 |
| Metal taste in the mouth | 2 | 11.1 |
| Nausea | 4 | 22.2 |
| Breathing | 3 | 16.7 |
| Gingivitis and mouth inflammation | 1 | 5.6 |
| Anorexia | 0 | 0 |
| Other | 1 | 5.6 |
| Total | 18 | 100.0 |




**Figure(4.24):Distribution of study group according toGeneral health status**

## 4.2 Discussion

A serum mercury concentration is one of mercury exposure biomarkers, Mercury is an element that cannot be destroyed, therefore Mercury already in use can be recycled for other essential uses, with no further need for mercury mining, Mercury use in artisanal and small-scale gold, Exposure to mercury vapor in gold mining is an occupational hazard and has been reported in several publications in different areas of the world . Human absorption of liquid Hg is minimal, and acute toxicity does not occur easily, but the problem arises when liquid mercury is heated and bursts into the gaseous phase, which causes acute interstitial pneumonia when inhaled at a high concentration. In the present study the traditional gold miners, work in a hot climate in a deserting area. As seen in the field they treat the mercury as if, a non-toxic substance, especially in washing stage to extract gold from washed stoned powder, and when heating the gold-mercury mixture to evaporate mercury and remain gold in metallic pans. The second source of exposure is that all the serious stages occur in the same area not exceeding few meters between stone milling, washing and molding. The third factor is low occupational awareness among the traditional gold miners. These reasons accumulated together, to find that the serum mercury among these miners are exposed to dangerously high levels . The study show that the average of mercury concentration in blood samples were 842.5 µg/L in burning and 2755 µg/L ,1405 µg/L and 2600 µg/L in washing ,mills and workers in shops respectively. The average of 18 mercury concentration in blood samples was 950 µg/L which indicated a high toxicity level, Similar finding was also reported in Abo hamad in 2014 gold miners was (24.9 ± 32.24µg/l) versus (1.40 ± 0.94µg/l) in the control group, another study in Iran was reported 208.14 µg/L and the average geometric mean of total Hg concentrations in the blood of was (10.05 µg/L) in colomiba.

The study show 61% of workers age were 19-35 years ,and 61% had directly contact with mercury.

The study show high incidents of neurological symptoms ,headache feeling stress , feeling weakness and eye Problems.

**Conclusions:**

The aim of the study was to evaluate mercury level in small gold mining activity at Abu hamad city in River Nile State,sudan . in this study the average of mercury concentration in blood was 950 µg/L which indicateda high toxicity level. The highest mercury concentration reported by this research 2775 µg/L , the reference sample non miner 29 µg/L and World Health Organization (WHO) the mercury concentration level 10 µg/L but the value of 20 µg/L or below is considered normal. The blood mercury concentration can rise to 35 µg/L after long-term exposure to mercury vapor the dtudy , high incidents of neurologicalsymptoms associated with neurotoxicity.

**Recommendation:**

- Interventional study should be done using chelatingtherapy.
- Renal toxicity should be evaluated in peopleliving in gold mining areas.
- Gold miners should use safety tolls (gloves, mask, etc.).
- Monitoring the environment and organic mercury in water.
- Workingtime in the mining area should be adjusted.
- Studies in city should be conducted to evaluate the community exposure to mercury including pregnant women and children at school age .

- Toxicological study should be conducted to measure mercuryin Nile river fish.
- Alternative technologies should be implemented to reduce mercury emission.

- National regional and global actions, both immediate and long-term, are needed to reduce or eliminate releases of mercury and its compounds to the environment. WHO is committed to work with the health sector and national, regional and global health partners to: reduce mercury exposure, eliminate the use of mercury wherever possible. and promote the development of alternatives to the use of mercury.

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48.adapted from WHO, 2004.

بسم الله الرحمن الرحيم

**Nile Valley University**

**Collage of Graduate Studies**

**Questionnaire about Assessment of Mercury levels In Blood Among Traditional Gold Mining workers In Abuhamad Area , River Nile state , Sudan from October 2019 to March 2020**

**1 - Age**

Less than 18 ☐

19 -35 ☐

36 -50 ☐

More than 50 ☐

**2- Marital Status**

Single ☐

Married ☐

**3- Job description**

Mills ☐

Mercury washing ☐

Mercury burning ☐

Workers in shops ☐

**4- Time Period of work**

1year ☐

2 year ☐

5year ☐

More than 5 years ☐

**5- Period of work**

Continuous ☐

Intermittent ☐

**6- History Of Working As Miner With Mercury Contact**

No ☐

Yes ☐

**7- Where they Stored Mercury container**

Home ☐

work ☐

Never store mercury ☐

**8- Feeling Weakness**

Same As Usual ☐

Worse Than Usual ☐

Much Worse Than Usual ☐

**9- Feel Sleepy Or Drowsy**

Same As Usual ☐

More Than Usual ☐

Much Worse Than Usual ☐

**10- Palpitation**

Never ☐

At Least Once A Day ☐

At Least Once A Week ☐

At Least Once A Month ☐

**11- Syncopal attack**

Yes ☐

No ☐

**12 - Chronic Disease**

No ☐

Yes ☐

**If yes mention it**

……

**Neurological symptoms**

**13-Headache**

Same As Usual ☐

More Than Usual ☐

Much Worse Than Usual ☐

**14-feeling stress and sadness**

Sometimes ☐

Often ☐

**15 - Eye proplems**

Conjunctivitis ☐

weakness of view ☐

**16- memory proplems**

normal ☐

abnormal ☐

**17 - Do you have any toxicity during work**

Yes ☐

No ☐

**If yes mention it …………**

**18- General health condition**

Cough ☐

Metal taste in mouth ☐

Respiratory problems ☐

Nausea ☐

Gingivitis ☐

Loss of appetite ☐

Others ………..