SCHOOL OF PUBLIC HEALTH, COLLEGE OF HEALTH SCIENCES, UNIVERSITY OF GHANA

EXPOSURE OF SMALL SCALE GOLD MINERS IN PRESTEA TO MERCURY, GHANA

By

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DECLARATION

This work is the result of an independent investigation under the supervision of Professor Col. A Edwin Afari (Rtd). Where my work is indebted to the works of others, I have made acknowledgement. I declare, therefore that this dissertation has not been presented elsewhere, either in part or in whole for another degree.

SIGNATURE……………………………………………

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DATE…………………

PROF. Col. EDWIN. A. AFARI (Rtd) (SUPERVISOR)

DEDICATION

This work is dedicated to Janet my dear wife, and children, Bethel, Stephanie, Ewurabena and Myra, who supported me throughout the course of my study. It is also dedicated to all Small Scale Gold Miners in Prestea for their co-operation throughout the study period.

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ABSTRACT

Background: Mercury is commonly used in Artisanal Small-Scale Gold Mining (ASGM) to amalgamate gold. Mercury use in ASGM is a global public health problem, since it is the world's fastest source of mercury contamination. Mercury is toxic even at low concentration and exposure is of great concern since it is a potent neurotoxicant. Mercury poisoning among small scale gold miners has been observed in many small scale gold mining regions across the world.

ASGM is a rapidly growing industry in Prestea where miners handle mercury without personal protective equipment (PPE). This study seeks to assess occupational exposure of small scale gold miners in Prestea to mercury.

Method: Morning urine samples were collected from 343 consenting small scale gold miners at their work sites in Prestea. A structured questionnaire was used to collect information from the miners. A work place assessments and interviews were conducted at the small scale gold mines. Urine samples were analyzed at the laboratory for elemental mercury. Univariate analysis was expressed as frequencies, percentages, mean±SD, tables and figures. Association between mercury exposure; adverse health effects and occupational exposure was determined at 95% CL.

Results: Of the 343 participants urine samples, 160(46.65%) of them exceeded the guideline value for individuals not occupationally exposed to mercury (<5.0ug/L). Of the 160 (46.65%) participants exposed to mercury, 122 (35.57%) of them, their urine mercury level was between (5.00-20.00ug/L), while the remaining 38(11.08%) had urine mercury level (>20.00ug/L). There were no significant association between mercury exposure; and complaints of skin rashes (χ^2=3.49, p=0.062), red eyes (χ^2=3.22, p=0.073), and metallic taste (χ^2=3.72, p=0.054). Complaints of numbness, however, were significantly associated with mercury exposure among participants who have previously worked at other small scale gold mines before moving to Prestea (χ^2=4.96, p=0.026). Standing in a pool of water or stream whiles working at the mining site (OR: 1.31, 95% CI: 0.81-2.09), sucking of excess mercury from the amalgam for re-use with the mouth (OR: 1.37, 95% CI: 0.78-2.39) and amalgamating with mercury (OR: 2.14, 95% CI: 0.77-5.94) were associated with mercury exposure; however, these were not significant. Majority 335 (97.7%) had no occupational safety training in handling mercury and the use of PPE among the participants was very low. Retorts for burning amalgam was not found at mining sites visited.

Conclusion: Small scale gold miners in Prestea are experiencing mercury exposure in excess of occupational exposure guidelines, and are at risk of mercury intoxication. Prestea Huni-Valley District Health Directorate, the Environmental Protection Agency and the Minerals Commission should organize regular medical screening and occupational safety training in handling mercury; and also mobilize retorts for burning gold amalgam for the small scale gold mining communities in Prestea.

Key words: ASGM, Mercury, Personal protective equipment, Prestea, Ghana

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LIST OF ABBREVIATIONS

ACGIH	American Conference of Governmental Industrial Hygienists
ASGM	Artisanal Small Scale Gold Mining
ATSDR	Agency for Toxic substances and Disease Registry
BEI	Biological Exposure Index
GH¢	Ghana Cedis
IPCS	International Programme on Chemical Safety
NIMOS	National Institute for Environment and Development in Suriname
Nm	Nanometres
Ppm	Parts per millions
UNEP	United Nations Environment Programme
WHO	World Health Organization
W/v	Weight per volume
V/v	Volume per volume

CHAPTER ONE

INTRODUCTION

1.1 Background

Mercury also known as quick silver is a chemical element with the symbol Hg and atomic number 80. It is a metal that is liquid at standard conditions for temperature and pressure. With a freezing point of -38.83$^{\theta}$C and a boiling point of 356.73$^{\theta}$C, mercury has one of the broadest ranges of its liquid state of any metal.

Mercury occurs in deposits throughout the world mostly as cinnabar (mercuric sulphide), which is the source of the red pigment vermillion, and is mostly obtained by reduction from cinnabar. Cinnabar is highly toxic by ingestion or inhalation of the dust.

Public Health Importance

Mercury is commonly used in artisanal small scale gold mining (ASGM) or informal mining to amalgamate gold. ASGM is responsible for 12% of the world's gold production or approximately 330 tons per year (Telmer and Veiga, 2008).

ASGM is of global public health concern. It is estimated that between 13 to 20 million small scale gold miners are directly involved in ASGM (Stablum, 2008) and support the livelihood of over 100 million people in 70 countries (Telmer and Veiga, 2008). ASGM is largely a poverty driven activity that constitutes an important source of livelihood for many rural communities, but it is also the world's fastest growing source of mercury contamination (Swain *et al.*, 2007).

In recent years, the use of mercury in ASGM has been drawing more and more concern at international and intergovernmental meetings (Ashton *et al*., 2007). During the 25th United Nations Environment Programme (UNEP) Governing Council meeting in February 2009, the participating countries decided to launch negotiations on an international mercury treaty to deal with world-wide use, emissions and discharges of mercury. The meeting also facilitated accelerated voluntary action on mercury with the Global Mercury Partnership as one of the key delivery vehicles. The overall goal of the partnership was to protect human health and the global environment from the release of mercury and its compounds by minimizing and, where feasible, ultimately eliminating global, anthropogenic mercury releases to air, water and land. The partnership was to work in areas where mercury is used including ASGM (UNEP, 2012). In all, ASGM is estimated to release up to 1350 tons of mercury to the global environment annually (Telmer and Veiga, 2008).

History of ASGM in Ghana

Ghana is one of the most important gold mining regions in the world [(Spiegel, 2009) and (Tschakert and Singha, 2007)]. Gold and diamonds were mainly mined on a small scale during the pre-colonial days. Gold was traded with the Moors and the Phoenicians on the Trans-Saharan trade routes before the advent of the Portuguese and other Europeans in 1471 (Anin, 1990).

Artisanal mining and processing methods were employed to work both hard rock and alluvial gold deposits. The Chief whose land was mined for gold was generally entitled to one-third of the gold won, and therefore sought to promote proper organization of the activities (Anin, 1990). Gold has been mined in Ghana for over 1000 years and its production has increased 700% since 1980 (Hilson, 2002).

The ASGM sector is very active in Ghana, and its importance is steadily growing (Jønsson and Fold, 2011). In 2000 it contributed to 9% of gold production and by 2010 that figure had grown to 23% (Ghana Minerals Commission, 2012). In 2010 the ASGM sector produced $800 million worth of gold and $11.3 million worth of diamonds (Ghana Minerals Commission, 2012). As of 2009 over 1 million people were directly dependent upon ASGM for their livelihoods in Ghana (Hilson, 2009). ASGM provides jobs for these people and in some it is their only source of income. These activities tend to reduce rural exodus in areas where ASGM are taking place.

Small scale gold miners are not allowed to work on mineral concessions owned by large scale or formal gold mining companies. Some of these small scale gold miners encroach on these concessions leading to conflicts between them and the large scale gold mines.

Some large scale gold mining companies have taken steps to regularize the activities of small scale gold miners working on their concessions. This was done by ceding portions of the concessions where the amounts of gold are too small and not economical to mine on large scale to the minerals commission for licensing to the small scale gold mines along the lines of statutory laws contained in the Mining and Explosives Regulations (Anon, 1970).

Several health concerns exists in small scale gold mining communities such as exposure to mercury, dust and noise, unsanitary working conditions and lack of personal protective equipment used in mining gold.

Reports also state that "Every week at least one person dies" as a direct result of the various pollution-related activities of these small scale gold miners in Ghana (Common Language Project, 2010).

Mercury is known to be toxic even at low concentrations (Zahir *et al*., 2005) and its exposure is of great concern since mercury is a potent neurotoxicant (Clarkson and Magos, 2006).

1.2 PROBLEM STATEMENT

Over 1 million Ghanaians are estimated to be working in the small scale gold mining operations (Hilson 2009). A small scale mining operation in Ghana is that which is based on a land plot measuring less than 25 acres (World Bank, 1995).The bulk of ASGM is concentrated in the Western part of Ghana especially Prestea. In Ghana, the main environmental problems associated with ASGM activities are mercury pollution from gold processing, ecosystems destruction and environmental degradation (Amegbey *et al.*, 1997; Hilson, 2002).

The careless handling of mercury is seen during visits to most small scale gold mining sites in Prestea, where most small scale gold miners are seen to be using mercury without appropriate respiratory and skin protection. Mercury is added to the gold containing ore and mixed by hand without gloves to form an amalgam. An amalgam is made up of approximately 60% Gold (Au) and 40% Mercury (Hg) (Figure 1). Subsequent burning of this amalgam over a charcoal fire releases mercury vapour. The released elemental mercury vapour poses both an occupational and environmental threat. Occupationally, those involved in small scale gold mining (both directly and indirectly) as well as residents may inhale high levels of elemental mercury.

The elemental mercury may be oxidized in the atmosphere and are deposited into nearby streams and rivers. Once in the aquatic system, the mercury is biomethylated by bacteria into methyl mercury. Methyl mercury biomagnifies through the fish in the aquatic systems, and thus poses a risk to those who consume fish. In Prestea, about 30% of

ASGM takes place in River Ankobra which passes through the town, and some miners also catch fish from the river for consumption.

Mercury poisoning among human residents has occurred in many small scale gold mining regions across the world such as Brazil (Lebel *et al*., 1998; Malm *et al*., 1989; and Palheta and Taylor, 1995), Indonesia (Limbong *et al*., 2003), Peru (Counter *et al*., 2006), Tanzania (Bose-O'Reilly *et al*., 2010) and Ghana (Adimado and Baah, 2002).

Personal conversation with a manager of a small scale gold mining sites in Prestea revealed that most small scale gold miners complain of persistent headaches and recurrent skin lesions, which he attributes to the use of mercury by the gold miners.

Despite the promulgation of mercury law in 1933 banning Ghanaian gold miners from using mercury in their operations, the practice continued (Akabzaa and Dramani, 2001; Hilson, 2001) till its legalization in May 1989 by Provisional National Defence Council Law 218. This legalization of small scale gold mining has escalated ASGM activities in Ghana especially Prestea.

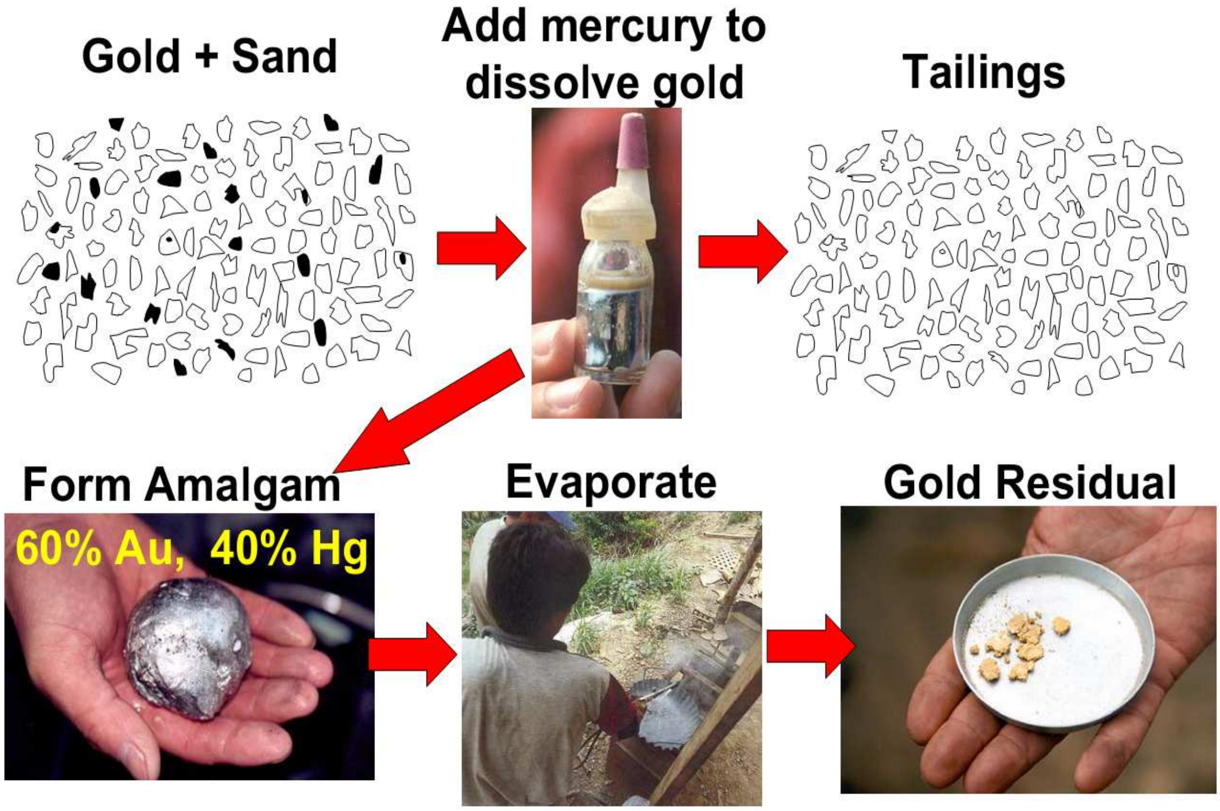

Fig 1: How mercury is used in Small Scale Gold mining

Source: Global Mercury Project; Mercury and Small Scale Gold mining-Magnitude and Challenges Worldwide.

1.3 JUSTIFICATION

Small scale gold mining is a rapidly growing industry in Prestea, but little is known about the level of occupational exposure to elemental mercury among small scale gold miners in this area. Although (Paruchuri *et al*., 2010) have reported high levels of urine mercury in a mining community located in the Talensi-Nabdam District in the Upper East Region of Ghana and (Kwansa-Ansah *et al*., 2010) also reporting low urine mercury levels among indigenous people in Dunkwa-on-Offin, in the Central Region of Ghana, no study has been done to determine occupational exposure to mercury among small scale gold miners in Prestea.

The study aims at determining occupational exposure to elemental mercury through the use of urine sampling and the factors contributing to these mercury levels. Research in this area will provide information concerning occupational exposure to elemental mercury due to small scale gold mining activities in Prestea. This information could be useful in eliminating the use of mercury and organization of programmes to reduce occupational exposure to mercury in Prestea.

1.4 STUDY HYPOTHESIS

The null hypotheses tested in this study were (a) Exposure to mercury by small scale gold miners in Prestea is not an indicator of any adverse health effects such as numbness and skin rashes. (b) Exposure to mercury is not associated with occupational factors such as amalgamation of gold and sucking of excess mercury form the amalgam with the mouth for re-use.

1.5.1 MAIN OBJECTIVE

To assess occupational exposure of Small scale gold miners in Prestea to mercury.

1.5.2 SPECIFIC OBJECTIVES

The specific objectives are:

1. To determine mercury levels in urine of small scale gold miners in Prestea.
2. To determine association between mercury exposure and any adverse health effects.
3. To determine prevalence of occupational factors associated with exposure to mercury by small scale gold miners in Prestea.

CHAPTER TWO

LITERATURE REVIEW

2.1 Forms of Mercury

Mercury exists in three different forms, namely Elemental mercury, Inorganic mercury and Organic mercury (Health Canada, 2009). Elemental mercury is a silver shiny volatile liquid which gives off colourless and odourless vapour at room temperature. Inorganic mercury is formed when elemental mercury combines with other elements such as sulphur, chlorine or oxygen to form compounds known as mercuric salts. Methylmercury is formed when elemental mercury combines with carbon.

2.2 Toxicokinetics of forms of Mercury

The Toxicokinetics (absorption, distribution, metabolism and excretion) of mercury is highly dependent on the form of mercury to which a person has been exposed.

Elemental mercury

In its metallic (liquid) form, elemental mercury is not significantly absorbed or transformed by the human digestive system; when ingested in this form, it is almost completely excreted in the faeces with little toxic damage (Rowland *et al*., 1997).

Similarly, skin contact with liquid elemental mercury results in relatively low absorption into the body, generally causing only mild symptoms (such as skin irritation, dermatitis, or cutaneous eruptions).

However, following inhalation exposure, the absorption of metallic mercury vapour occurs efficiently and rapidly through the lungs.

About 80% of inhaled vapours are absorbed by the lung tissues. Once absorbed, metallic mercury vapour is readily distributed throughout the body; it crosses both placental and blood-brain barriers (ATSDR, 1999). Elemental mercury can be retained in the brain with detectable levels present for years following exposure (Matsuo *et al*., 1989).

Inorganic mercury

Common routes of exposure include the gastrointestinal tract, oral ingestion and the skin. The highest accumulation of inorganic mercury occurs in the kidney. Inorganic mercury does not cross the blood-brain barrier or the placenta easily, but the slow elimination and the fact that exposure often takes place over a long period of time allows for significant central nervous system accumulation of mercuric ions and subsequent toxicity (Broussard *et al*., 2002).

Methylmercury

The dominant route of exposure to methylmercury is through the ingestion of fish. While the gastrointestinal tract is the primary route of absorption, methylmercury can be absorbed through the skin and the lungs as well. This form of mercury is distributed throughout the body and easily penetrates the blood-brain and placental barriers.

Methylmercury enters the brain where it is oxidized and accumulated and eventually causes chronic exposure and, depending on the level of exposure can lead to adverse human health effects (Kanai and Endou, 2003).

2.3 Clinical Signs and Symptoms of mercury

Mercury poisoning is frequently misdiagnosed because of the insidious onset coupled with non specific signs and symptoms. The clinical presentation of an individual exposed to mercury depends upon the dose, the length of and form of exposure.

Acute toxicity is more commonly associated with the inhalation of elemental or ingestion of inorganic mercury. Chronic toxicity is more common from exposure to organic mercury. Irrespective of the chemical form of mercury present, the kidneys and the central nervous system are the two primary target organs of toxicity. All mercury compounds concentrate in the kidney to some extent.

Acute exposure caused by inhaled elemental mercury can lead to pulmonary symptoms. Initial signs and symptoms, such as fever, chills, metallic taste and pleuritic chest pain may occur. Other possible symptoms could include stomatitis, lethargy, confusion and vomiting.

Chronic exposure usually results from prolonged occupational exposure to elemental mercury that is converted into the inorganic form. Chronic and high dose acute mercury exposure produces a variety of renal, neurological, psychological and cutaneous symptoms. The exposed individual may experience rather vague and non-specific symptoms, including weight loss, fatigue, anorexia and muscular weakness that could be indicative of a number of diseases.

2.4 Mercury Exposures

General population exposure to mercury can occur from a wide variety of sources, (Poulin and Gibb, 2008) and these include contact with mercury containing products (e.g.

Thermometers, barometers, batteries, paints), exposure from dental amalgams fillings, ingestion of mercury contaminated food or drinking water.

2.5 Exposure Biomarkers

Exposure to mercury can be estimated by measuring the mercury levels in various body tissues such as hair, blood, cord blood, urine, human milk and nails. These measurements also known as biomarkers are useful tools for human exposure assessment. They are therefore sensitive indices used 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 (IPCS, 2000). The presence of mercury in urine generally represents exposure to elemental and /or inorganic mercury, and the collection is non- invasive. Urine mercury levels are considered the best measure of recent exposure to elemental mercury vapour or inorganic mercury.This is because urinary mercury indicates most closely the mercury levels present in the kidneys (Clarkson *et al*., 1988). Inorganic mercury accumulates in kidney and is slowly excreted through the urine, therefore urine mercury levels can also represent exposures to elemental mercury and /or inorganic mercury that occurred sometimes in the past.

Mercury has been recognized as a significant environmental and public health problem for more than 40 years, mainly for its effects on the developing nervous system as expressed in tragic episode of human poisoning in Japan and Iraq (National Research Council, 2000). Mercury continues to be used in ASGM throughout the world, especially Africa, South America, Asia, and North America (Lacerda and Salmon,1998).

The Intermediate Technology Development Group (ITDG), a non-governmental agency providing technical assistance in selected regions of the world defines Small-scale miners or informal miners as ‘poor people, individuals or small groups who depend upon mining for a living, who use rudimentary tools and techniques (e.g. pick axes, chisels, sluices and pans) to exploit their mineral deposits’(ITDG, 2001). ASGM in Ghana is popularly called *Galamsey* (Gather them and sell). Residents in mining towns in Ghana have over the years express their concern over the activities of these small scale gold miners as they pollute their rivers used for drinking and other natural resources, mainly because of the use of mercury in amalgamating the gold ore.

The use of mercury to recover gold or amalgamation is a simple extraction process, but it is dangerous and contaminates air, soil, rivers, and lakes. Numerous health problems can result from exposure to mercury such as skin lesions, kidney problems, metallic taste and frequent fever.

Although scientist have known mercury to be a toxic substance for many decades (Neal PA, 1938), it was not until the 1980s, that the widespread use of metallic mercury at the Garimpo gold mining operations in the Amazon region of Brazil attracted world attention (Ikingura JR, 2001). Most large scale mining companies have since phased out mercury use in their operations, often switching to cyanide processing, posing another set of various human and environmental health risks (Hilson and Monhemius, 2006).

Mercury poisoning is now commonly considered as an “invisible epidemic” and a “chemical time bomb” because its impacts are usually not seen immediately but can bioaccumulate in the food chain and creates new dangers once transformed into methylmercury (Lacerda and Salomons, 1998). The health of people living in mining areas are also negatively affected through inhalation of mercury vapour, direct contact with mercury, and the consumption of fish and other foods affected by mercury contamination(Castilhos ZC *et al*., 2006).

Urine mercury levels have been reported in different units of measurement [micrograms per litre (ug/L) and micrograms per gram creatinine(ug/g creatinine)] by various researchers. The unit of urine mercury for this study was ug/L.

Early signs of mercury intoxication can be seen in workers excreting more than 50ug/L of mercury in urine. This value 50ug/L or 50ug/g creatinine has been proposed by many experts as the biological threshold limit or guideline value for chronic exposure to mercury vapour, and in 1980 this was endorsed by WHO (WHO, 1980). The guideline value for mercury in urine of individuals not occupationally exposed is less than 5.0ug/L (Oosthuizen MA *et al*., 2010). While a threshold value of 50ug/L mercury in urine is used to gauge risk, health effects such as tremors and inco-ordination have been documented in studies of occupationally exposed individuals with urine levels less than 50ug/L (Clarkson and Magos, 2006).

A study in Peru, focusing on gold smelters and those living in the vicinity found high levels (mean 728ug/L) of mercury in the urine of those directly involved in smelting of gold. (Hurtado J *et al*., 2006). A survey by Nanjid K *et al*., 2008 in gold mining villages in Mongolia among informal gold miners (exposed) and women (controls) found informal miners having urine mercury higher than the control groups. A field study that investigated mercury levels in urine and hairs of children in a gold mining settlement

Nambija, Ecuador detected a mean urine mercury level of 10.9ug/L and mean hair mercury of 6.0ug/L (Counter SA *et al*., 2005).

WHO, in March 2008 conducted a study in Khongor Soum, Mongolia in response to release of mercury into the environment as a result of gold mining. The study found 3.7% of the local population having measurable urine mercury concentration that were below levels representing a health concern (7ug/L, as defined by the German Human Biomonitoring Commission) (WHO, 2008). Drake *et al*., 2001 in a cross sectional study in a mining area near El Callao, Venezuela among gold miners found 42% of the study population having urine mercury concentrations that exceed the American Conference of Governmental Industrial Hygienists (ACGIH) biological exposure Index (BEI) of 35ug/g creatinine. The mean urine mercury concentration was 101ug/g creatinine.

Umbangtalad *et al*., 2007 in Thailand detected that school children attending an elementary school near a gold mine site showed indirect exposure to mercury from the adults working in mining areas. Another study of Peruvian children of ASGM miners also found 85% of the sampled children having high levels of mercury in their urine, blood and hair (Counter *et al*., 2006).

In Tanzania, Van Straaten P, 2000 found 36% of individuals involved in amalgamation of gold having urine mercury levels that were between 50 and 100ug/g creatinine. Oosthuizen MA *et al*., 2010, however, found 50% of participants having urine samples that exceeded the guideline for mercury in urine (< 5.0ug/L) for those not occupationally exposed in South Africa.

A study in Rwamagasa, a fast growing mining area in Tanzania detected higher levels of mercury in the urine, hair and blood of villagers as compared to the control group, however, only amalgam burners showed extremely high levels (Bose-O'Reilly S *et al*., 2007). Tomicic *et al*., 2011 in Burkina Faso found 69% of workers belonging to eight different gold mining sites having levels of urinary mercury that exceed ACGIH biological exposure index of 35ug/g creatinine, while 16% exceeded 350ug/g creatinine.

A cross sectional study by Paruchuri *Y et al*., 2010, to determine occupational and environmental exposure to mercury in a mining community located in the Talensi-Nabdam District in the Upper East Region of Ghana, found 21% of the participants having moderately high levels of urinary mercury(>10ug/L), and 5% urine mercury levels that exceeded the WHO guideline value of 50ug/L.Urine mercury levels was higher among miners who burn amalgam.The study did not find significant association between urine and hair mercury and the following health outcomes, fatigue, bodyache, neurological, infectious disease, diarrhoea, breathing difficulty, vision and cardiovascular function.

In a study by Adimado and Baah, 2002, of people living near small-scale gold mining sites in south western Ghana, 68% of the participants had urine levels that ranged between 50 and 200ug/L.

In contrast, a case control study by Kwaansa-Ansah *et al*., 2010 to determine environmental and occupational exposures to mercury among indigenous people in Dunkwa-on-Offin, in the Central Region of Ghana found levels of mercury that do not appear to pose a significant health threat to the people. The range of mercury levels among the small-scale gold miners was 0.32 to 3.62ug/L and that of the farmers, control group, was 0.075 to 2.31ug/L.

Branches *et al*., 1993 reported a study of patients from the Amazon regions that were self referred with symptoms of mercury toxicity. Sixty percent of the subjects had direct occupational exposure to mercury from gold mining and refining; however, correlations between mercury exposure and severity or frequency of symptoms were not evaluated. In Tanzania, Harada *et al*., 1999 reported frequency of symptoms of mercury toxicity among a population of gold miners and processors.

CHAPTER THREE

METHODS

3.1 Study design

This cross sectional study was conducted among small scale gold miners in Prestea. A structured questionnaire was administered and urine samples collected. Work place assessments through direct observation and interviews were conducted at the mining sites including shops where amalgam burning takes place to assess occupational exposure.

3.2 Study area

The study was carried out in Prestea which is an old gold mining town in the Prestea Huni-Valley District of the Western Region (Figure 2). For over 100 years, Prestea, which is in the South-West of Ghana, approximately 22.8 kilometres from Tarkwa in the Western Region has been an important location for both large and small scale gold mining. According to Ghana Chamber of Mines, to date, more than eleven million ounces of gold have been produced in Prestea and Bogoso towns.

Prestea has a population of 33,789 (Annual Health Sector Report 2011, Prestea Huni-Valley District) and 13 communities. The town has two main large scale gold mining companies namely Golden Star and Sankofa gold limiteds. Small scale gold mining activities is widespread in the town, employing more than 1000 people with some coming from other parts of the country. These activities using mercury create ecological changes such as pollution of streams and rivers, destruction of aquatic system and creation of pools in place of free flowing streams and rivers that increases breeding of mosquitoes leading to high incidence of malaria infections. Apart from mining, farming and trading also occur in the town.

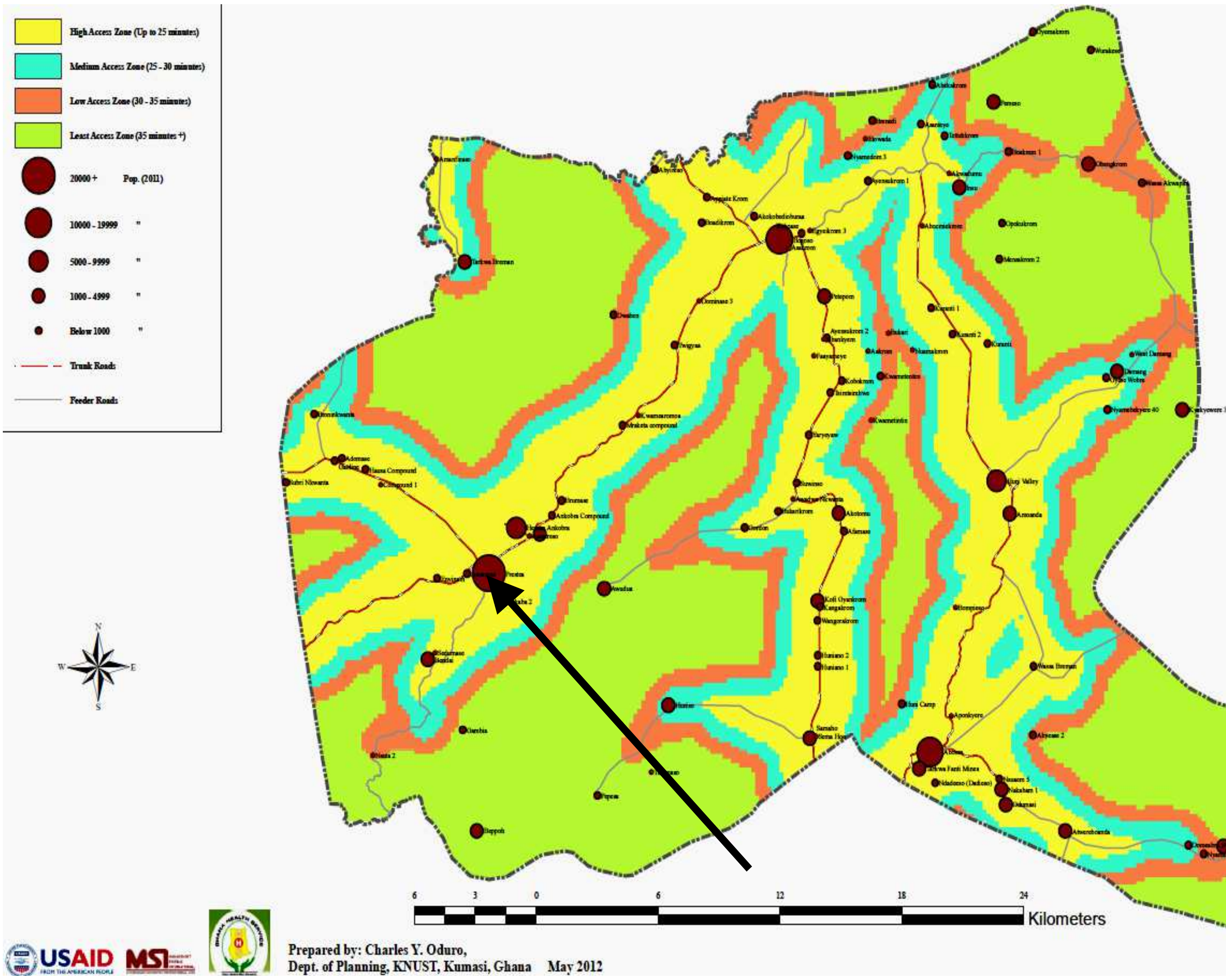

Fig 2: Map of Prestea Huni-Valley District showing the study site Prestea (arrowed)

3.3 Table 1: Variables

Dependent Variable	Independent Variables
Mercury Exposure	• Socio-demographics (Gender, Age, Educational level, Marital status, Ethnicity, Nationality).
	• Occupational exposure and safety; includes the following: (Number of years worked, Number of days worked per week, Number of hours spent at the mines per day, Amalgamating with mercury, Burning of amalgam, Smelting of Gold, Transporting of Mercury, Transporting of Ore, Standing in pool of water/stream whiles working, Sucking of excess Mercury from the amalgam for re-use, Use of personal protective equipments, Knowledge of mercury hazards, working previously at other small scale gold mines).
	• Signs and symptoms of mercury exposure (Skin rashes, Red eyes, Frequent cough, Persistent fever, Persistent headaches, Metallic taste, Fatigue, Muscle aches, Sinusitis, Insomia, Numbness and Hair loss).

3.4 Study population

The study populations were small scale gold miners staying in Prestea and involved in small scale gold mining at the time of the study.

3.5 Inclusion criteria

Small scale gold miners engaging in small gold scale mining in Prestea were eligible for the study.

3.6 Exclusion criteria

Failure to obtain an informed consent and persons not engaging in small scale gold mining in Prestea were excluded from the study.

3.7 Sample size determination

Using a prevalence of 68% of mercury exposure among small scale gold miners in South-Western Ghana (Adimado and Baah, 2002), and an allowable error of 5% at 95% confidence level, a minimum sample size of 334 was obtained, however, 343 participants were recruited in to the study.

3.8 Sampling methods

Of the twenty five small scales gold mining sites scattered in Prestea, twenty sites were conveniently selected based on accessibility of the sites with the guidance of the chairpersons of the small scale gold mining association since some of the sites were located deep in the forest. At each site at least seventeen participants were randomly selected using the lottery method with replacement at the time of data collection and consented to the study, after the purpose of the study have been explained to them, where any of them fits the inclusion criteria giving a maximum sample size of 343.

3.9 Data collection

The structured-questionnaire for data collection was pretested at Bondaye a town near Prestea. It was then administered to the 343 consenting participants by 5 trained health workers to document their socio-demographics characteristics, occupational exposure and safety, and presence of signs and symptoms suggestive of mercury exposure.

3.10 Urine Sample collection and Transportation

Morning urine samples were collected from each consenting participant at the work site after a questionnaire has been filled into polyethylene mercury free plastic bottles which can collects between 20-50ml of urine. All urine samples were kept in cold boxes containing ice packs with a thermometer to maintain a temperature between 2^{θ}C to 8^{θ}C in the field, and returned to a fridge at Prestea Government Hospital Laboratory each day at the same temperature range. For every 30ml of urine 2ml of 5% v/v Nitric Acid was added to digest mercury into its inorganic forms. All urine containers bore the identifying numbers of participants only. Safety precautions were employed in the collection and transportation of urine samples.

Samples were sent to the Water Research Institute Laboratory in Accra in cold boxes with ice packs and a thermometer to maintain a temperature between 2^{θ}C to 8^{θ}C for mercury analysis. The Heavy Metals Laboratory of Water Research Institute, Council for

Scientific and Industrial Research, in Accra has a mandate to conduct research into water and related resources.

3.11 Laboratory Analysis

Principle of CVAAS

The Cold Vapour Atomic Absorption Spectrophotometer (CVAAS), machine model AA240FS, 200 SERIES AA, ACCESSORY VGA 77, AGILENT TECHNOLOGIES, with a detection limit of 0.01ug/L was used for the analysis. Both Oosthuizen *et al*., 2010 and Kwaansa-Ansah *et al*., 2010 also used CVAAS to determine urinary mercury.

The method involves reduction of mercury compounds by Stannous chloride to metallic mercury. It is then vaporized in a stream of air, and swept through an absorption cell placed in the path of a hollow cathode lamp beam. Mercury in the urine samples are measured at a wavelength of 253.7nm. The amount of light absorbed by mercury atoms is directly proportional to the amount of elemental mercury in the urine sample

In the laboratory all glassware for the mercury analysis were soaked in a commercially prepared phosphorus-free liquid soap which contains Sodium tri-polyphosphates for 24 hours. They were then rinsed with distilled water four times and further soaked in 5% v/v Nitric acid for five hours. These were then rinsed with distilled water four times before being used. This cleaning process was done to remove dirts and ions that might interfere with the mercury analysis. All urine samples to be analyzed daily were brought from the cold boxes containing ice packs to attain room temperature before being analyzed.

A sample capillary tube in the machine was placed in 2ml each of a well mixed urine sample to be measured in a glass test tube. The Vapour Generation Accessory 77 (VGA) then pumps the urine sample through a reaction cell where it is automatically acidified and mixed with a reductant (25% w/v Stannous chloride in 20% v/v Hydrochloric acid). The resulting vapour is transferred to an atomization cell by the machine for determination by the spectrophotometer at a wavelength of 253.7nm.

The concentration of elemental mercury in the urine sample was displayed on a computer connected to the CVASS expressed in ug/L.

Urine sample exceeding the guideline value for individuals not occupationally exposed to mercury (<5.0 ug/L) was defined as Mercury Exposure.

3.12 Laboratory Quality Control

Urine mercury determinations were calibrated to obtain a calibration curve by preparing three mercury standards (10ug/L, 20ug/L and 50ug/L) from a commercially prepared mercury stock standard of 1000ppm in 0.5M Nitric acid. These calibration standards were prepared fresh for each batch of 25 samples run daily; and run in parallel with the test urine samples and a commercially prepared quality control mercury sample.

3.13 Data processing

All data were handled anonymously and confidentially. Data sheets were completed and signed by study investigators only. These were stored in bound folders while in use, and then secured in locked metal cabinets until data entry.

3.14 Data analysis

Data were coded, entered and analyzed using Statistical Package for Social Sciences (SPSS) Windows version 16.

Exploratory analysis was carried out to obtain descriptive statistics such as frequencies, percentages, mean±SD, figures and tables. Chi-square (Pearson) test was used to determine the association between mercury exposure and any adverse health effects at 95% confidence level.

Binary logistic regression model was used to analyze occupational factors associated with mercury exposure and to generate prevalence odd ratios (OR) at 95% confidence level.

3.15 Ethical Considerations

Ghana Health Service Ethics Review Board gave their approval for the commencement of the study following a thorough review of the proposal. Permission was sought from the Prestea Huni-Valley District Assembly and the Chairpersons of the Small-Scale Gold Mining Association in Prestea**.** Participants were fully informed about the purpose, procedures, risks, and benefits of participating in this study. Informed consent was sought from participants before recruitment. Names of participants exposed to mercury were given to the Prestea Huni-Valley District Health Directorate for medical attention.

CHAPTER FOUR

RESULTS

4.1 Demographic characteristics

Of the 343 participants, 94.2% were males (Table 2). The ages of the participants ranged from 15-70 years with a mean age of 29.46 ±9.64 years. Majority of the participants were within the age group 20-29 years, 154(44.9%) (Table 2). The duration of work among the participants ranged from 1-38 years with a mean occupational exposure of 7.19 ± 6.96 years. The number of hours spent at the small scale mining sites by participants per day ranged from 1-24 hours with mean hours spent per day of 9.10 ± 3.66 hours. The number of days worked per week by participants ranged from 1-7 days with a mean number of days worked per week of 5.71 ± 1.29 days.

The educational level of the participants were low 209 (60.9%), 167 (60.9%) are married and majority of them are of Akan ethnicity 243 (68.2%) (Table 3). There was one Nigerian among the participants (Table 3). Overall, 266 (77.6%) of the participants prefer going to pharmacy and chemical shops to buy drugs for their ailments instead of seeking medical care at the hospital (Table 4).

Table 2: Demographic Characteristics of Study Participants (N=343)

Gender	Frequency	Percentage (%)
Male	323	94.2
Female	20	5.8

Age	Frequency	Percentage (%)
19 years and below	44	12.8
20 – 29 years	154	44.9
30 – 39 years	88	25.7
40 – 49 years	48	14.0
50 – 59 years	5	1.5
60 years and above	4	1.2

Educational Level	Frequency	Percentage (%)
None	33	9.6
Primary Education	209	60.9
Secondary Education	88	25.7
Tertiary Education	13	3.8

Table 3: Demographic Characteristics of Study Participants (N=343)

Marital Status	Frequency	Percentage (%)
Single	161	9.6
Married	167	60.9
Divorced	13	25.7
Widowed	2	3.8

Ethnicity	Frequency	Percentage (%)
Akan	243	68.2
Ewe	3	0.9
Ga-Adangbe	7	2.0
Dagaaba (Respondents from the three Northern Regions)	99	28.9

Nationality	Frequency	Percentage (%)
Ghanaian	342	99.7
Nigerian	1	0.3

Table 4: Areas where participants seek help when faced with health problems (N=343)

Area	Frequency	Percentage (%)
Pharmacy/Chemical shop	266	77.6
Hospital	71	20.7
Traditional healers	6	1.7

The study found 160 (46.65%) occupational mercury exposure among the participants. Mercury exposure level was defined as between (5.00-50.50ug/L) and 183 (53.35%) not exposed to mercury (<5.00ug/L) (Figure 3). Urine mercury level among the participants ranged from 0.01-50.50ug/L with a mean urine mercury of 8.17 ± 9.37ug/L.

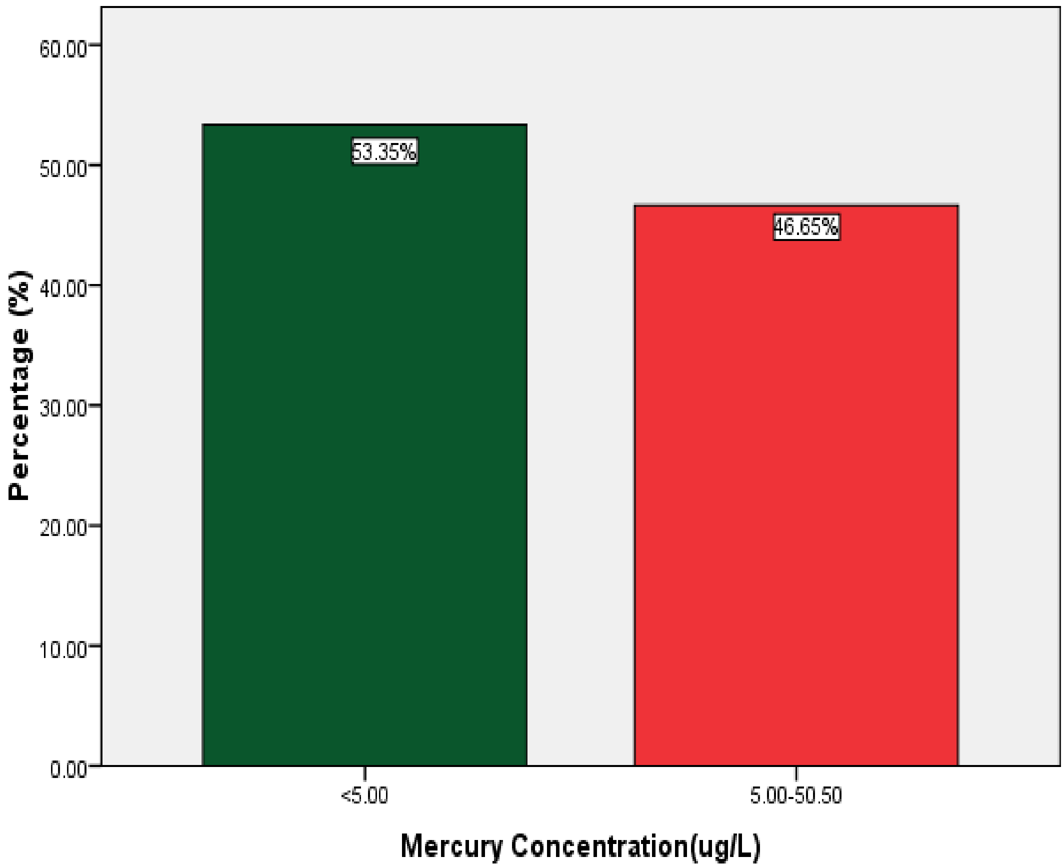

Fig 3: Urine Mercury levels among Small scale Gold Miners in Prestea

Of the160 (46.65%) participants exposed to mercury, 122 (35.57%) of them, their urine mercury level was between (5.00-20.00ug/L), while the remaining 38(11.08%) had urine mercury level (>20.00ug/L) (Figure 4).

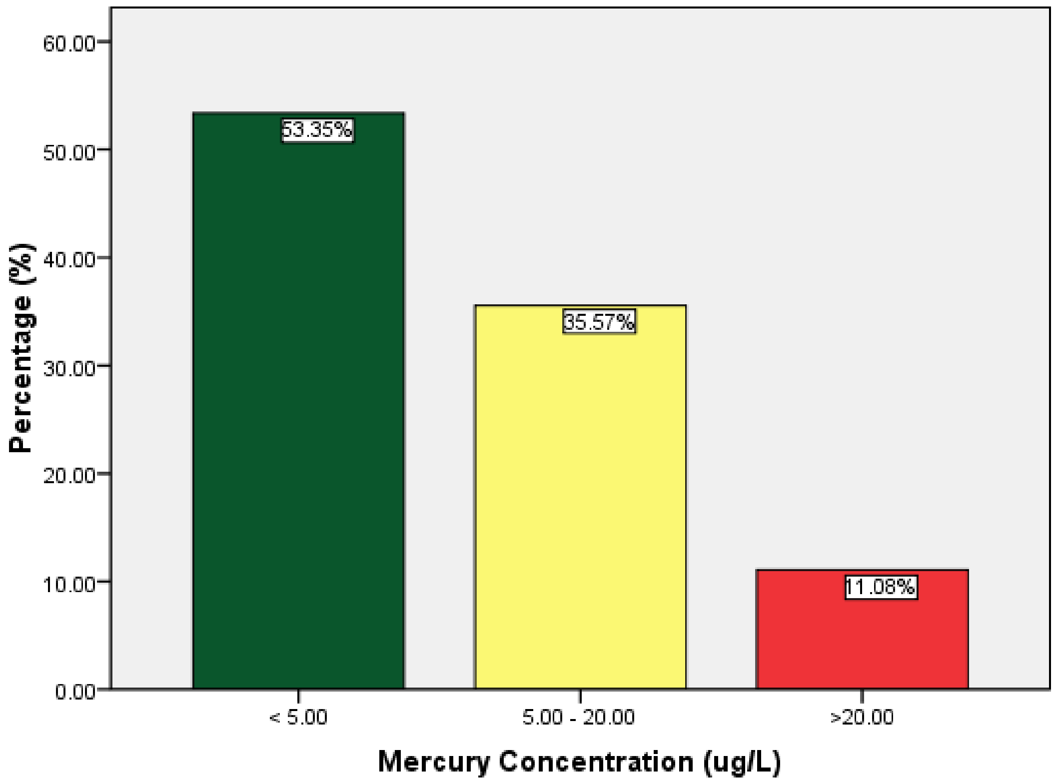

Fig 4: Distribution of cases at different concentrations of mercury in urine

4.2 Occupational exposure factors and safety

Amalgam burning was the most common occupational exposure factor 157(19.2%) among the participants whiles 49 (6.0%) suck excess mercury from the amalgam with their mouth for re-use (Table 5).

Also, 236(68.8%) of the participants store mercury at home; though 225(65.6%) of them had no knowledge about hazards associated with mercury use and neither have majority 335(97.7%) had occupational safety training in handling mercury (Table 6).

The use of personal protective equipment (PPE) among the participants was very limited. Three hundred and thirty-six (98.0%), 315(91.8%), 321(93.6%), 310(90.4%) and 314(91.5%) reported that they do not use rubber aprons, face masks, rubber gloves, leather boots and head coverings respectively whiles working at the mines (Table 7).

Table 5: Occupational exposure factors (N=343)

Occupational Exposure Factors	Frequency	Percentage (%)
Amalgamating with mercury	153	18.7
Burning of Amalgam	157	19.2
Smelting of Gold	112	13.7
Transporting of Mercury	148	18.1
Transporting of ore	85	10.4
Standing in pool of water/stream whiles working	115	14.0
Sucking excess Mercury from the Amalgam for re-use	49	6.0

Table 6: Participants knowledge about mercury hazards, occupational safety training and other activities performed at the mines (N=343)

Knowledge, Training and other Activities	Response	Frequency	Percentage (%)
Main Source of Drinking Water	Borehole	43 (N=340)	9.6
	Pipe Borne Water	15 (N=340)	3.3
	River/Stream	76 (N=340)	16.9
	Sachet Water	315 (N=340)	70.2
Consumption of fish from Ankobra River	No	325	94.8
Previously worked at Goldsmith shop	Yes	14	4.1
Knowledge about hazards associated with mercury use	No	225	65.6
Storage of Mercury	Home	236	68.8
Occupational Safety Training	No	335	97.7
Worked at other mines before arriving at Prestea	Yes	25	7.3
Movement between mines	Yes	16	4.7

Table 7: Participants use of Personal protective equipments (N=343)

Personal protective equipment	Frequency	Percentage (%)
Rubber Aprons		
-Seldom	3	0.9
-Don't use	336	98.0
Face Masks		
-Seldom	14	4.1
-Don't use	315	91.8
Rubber Gloves		
-Seldom	16	4.7
Don't use	321	93.6
Leather Boots		
-Seldom	15	4.4
-Don't use	310	90.4
Head Covering		
-Seldom	12	3.5
-Don't use	314	91.5

4.3 Reported signs and symptoms of Mercury exposure

Out of the twelve reported signs and symptoms by the participants, an association was found between mercury exposure and complaints of skin rashes; however, this finding was not significant (χ^2=3.49, p=0.062) (Table 8).

Table 8: Association between Signs and symptoms; and Mercury exposure (N=343)

Signs and Symptoms	χ^2	P- Value
Red eyes	0.26	0.608
Skin rashes	3.49	0.062
Frequent cough	0.23	0.629
Persistent fever	0.07	0.788
Persistent headache	0.69	0.405
Metallic taste	0.37	0.544
Fatigue	0.01	0.930
Muscle aches	0.14	0.706
Sinusitis	0.40	0.525
Insomnia	0.96	0.327
Numbness	0.00	0.959
Hair loss	0.04	0.839

Of the twenty five participants who reported working previously at other small scale gold mining sites before coming to work in Prestea, an association was found between complaints of red eyes (χ^2=3.22, p=0.073), metallic taste (χ^2=3.72, p=0.054) and mercury exposure; however, this findings were not significant. Complaints of numbness were however significantly associated with mercury exposure among this group of participants (χ^2=4.96, p=0.026) (Table 9).

Table 9: Association between signs and symptoms; and mercury exposure among participants who have previously worked at other small scale gold mining sites (N=25)

Signs and Symptoms	χ^2	P- Value
Red eyes	3.22	0.073
Skin rashes	0.33	0.566
Frequent cough	0.37	0.546
Persistent fever	0.37	0.539
Persistent headache	0.67	0.412
Metallic taste	3.72	0.054
Fatigue	1.97	0.160
Muscle aches	0.11	0.739
Sinusitis	0.00	0.959
Insomnia	2.39	0.122
Numbness	**4.96**	**0.026**
Hair loss	0.81	0.369

4.4 Occupational Exposure Factor Analysis

Standing in a pool of water or stream whiles working at the mining site (OR: 1.31, 95% CI: 0.81-2.09) and sucking of excess mercury from the amalgam for re-use with the mouth (OR: 1.37, 95% CI: 0.78-2.39) were associated with mercury exposure; however, the association was not significant. Individuals amalgamating with mercury were two times more likely to have been exposed to mercury. This was also not significant (OR: 2.14, 95% CI: 0.77-5.94) (Table 10).

Table 10: Multivariate analysis of Mercury Exposure and Occupational Factors (N=343)

Occupational Factors	Odds Ratio	95%(CI)	P-Value
Amalgamating with mercury	2.14	(0.77-5.94)	0.144
Burning of amalgam	0.70	(0.25-1.91)	0.488
Smelting of gold	0.82	(0.41-1.39)	0.467
Transporting of mercury	1.03	(0.46-2.30)	0.937
Transporting of Ore	1.00	(0.61-1.63)	0.989
Standing in a pool of water/stream whiles working	1.31	(0.81-2.09)	0.261
Sucking of excess mercury for re-use	1.37	(0.78-2.39)	0.266

Interview with the participants, revealed that they buy mercury from gold buyers and shops in Tarkwa, Prestea and Bogoso. These gold buyers normally bring the mercury from Tema in cylinders. The mercury is sold to the small scale gold miners at GH¢ 30.00 per tablespoonful of mercury. When asked to see how mercury looks like, the small scale gold miners poured the mercury from a small rubber bottle into their bare hands and rubbed it without wearing gloves. At three amalgams burning sites visited, with one located in a compound house, amalgam burning was being done without any protective equipment and the sites had very little ventilation. Some of the small scale gold miners were seen coughing during the amalgam burning, and there was very little use of PPE at small scale gold mining sites (Figure 5).

Fig: 5 Small scale gold miners in Prestea working in a pool of water (arrowed)

CHAPTER FIVE

DISCUSSION

5.0 Discussion

Mercury has been recognized as a significant environmental and public health problem for more than 40 years, mainly for its effects on the developing nervous system as expressed in tragic episode of human poisoning in Japan and Iraq (National Research Council, 2000).

Mercury is commonly used in ASGM to amalgamate gold. Mercury is favoured over other methods of gold extraction because of ease of use and ready accessibility. Individuals involved in burning gold amalgam and amalgamating with mercury without PPE are at significant risk of mercury intoxication. This study was to assess occupational exposure to mercury by use of urine sampling among small scale gold miners in Prestea.

This study found 46.65% of the participants urine samples exceeding the guidelines value for individuals not occupationally exposed to mercury (<5.0ug/L). This finding is similar to studies conducted in South Africa, Brazil and Venezuela where estimated urine mercury concentrations among small scale gold miners were 50%, 48.3% and 52% respectively above the recommended occupational exposure limits (Oosthuizen *et al*., 2010; Rojas *et al*., 2001; Sibergeld *et al*., 2002).

Tomicic *et al*., 2010, however, reported 69% of small scale gold miners having urine mercury levels above the recommended occupational exposure limits in Burkina Faso. The range of mercury levels in this present study was between 0.01-50.50ug/L. A study by Kwaansa-Ansah *et al*., 2010 to determine environmental and occupational exposures to mercury among indigenous people in Dunkwa-on-Offin, in the Central Region of Ghana found levels of mercury that do not appear to pose a significant health threat to the people. The range of mercury levels among their small-scale gold miners was between 0.32 - 3.62ug/L.

These exposure differences could be due to different levels of occupational mercury exposure among the small scale gold miners at the various small scale gold mining communities.

The findings in this present study show that participants living in Prestea and working in small scale gold mining communities are potentially exposed to mercury. These small scale gold miners exposed to mercury are probably at risk of experiencing adverse health effects and mercury intoxication.

The WHO considers 4ug/L total mercury (not adjusted for creatinine levels) in urine to be normal; a concentration higher than 5ugHg/g creatinine as experiencing health effects; and a concentration above 20ugHg/g creatinine a probable risk of mercury intoxication(Veiga *et al*., 2006).

Complaints of skin rashes, red eyes and metallic tastes were found to be associated with mercury exposure, though not significant, complaints of numbness were significantly associated with mercury exposure among participants who have previously worked at other small scale gold mining sites before coming to work in Prestea. This could be attributed to continuous, higher and longer occupational mercury exposure among this group of small scale miners. Paruchuri *et al*., 2010 and Rojas *et al*., 2001 did not find any significant association between mercury exposure and frequency of reported symptoms of mercury among their study participants, probably due to the small sample size used in their study. Schwartz *et al*., 1992, however, observed red eyes and conjunctivitis being reported by individuals exposed to high concentration of elemental mercury vapours.

This study found low educational level (primary) among the participants; this may explain the reason why the use of PPE was low among the participants. This low level use of PPE is consistent with findings by Rojas *et al*., 2001. Other possible explanation for this includes lack of knowledge and apathy towards mercury exposure. As majority of the study participants had no occupational safety training in handling mercury, training is necessary to raise the small scale gold miners awareness about safety and hazards associated with handling mercury. A study by Hilson *et al*., 2007 in the Talensi-Nabdam District of Ghana also found that small scale gold miners were unaware of the health risks of mercury, and they were also not using PPE.

Individuals amalgamating with mercury in this study were two times more likely to have been exposed to mercury at the time of the study. Studies by Paruchuri *et al*., 2010 and Bose-O'Reilly S *et al*., 2007, however, found amalgam burners significantly having higher urine mercury. Their amalgam burners may probably have been exposed to higher and continuous mercury vapour compared to those in this present study.

After inhalation of mercury vapour during amalgam burning approximately 80% crosses the alveolar membrane and is rapidly absorbed into the blood stream. Absorbed elemental mercury is rapidly distributed to all tissues, although it accumulates to the greatest extent in the kidney, reaching between 50 and 90 % of the body burden (WHO 2003). It reaches peak levels in all tissues within 24 hours, apart from the brain where peak levels are only reached after 23 days. Some of the small scale gold miners during this study were seen removing excess mercury from amalgam through a process of hand squeezing using a piece of cloth without gloves; whereas others sucked the mercury from the amalgam with their mouth for re-use. This is normally done before burning of the amalgam over an open-fire without PPE. Amalgam burning may contribute to elevated air and dust levels of mercury, and residents in Prestea staying around places where amalgam burning takes place may also inhale high levels of mercury vapour.

A retort which is recommended by UNEP (UNEP, 2008) to be used during amalgam burning was not found at small scale gold mining sites visited. Their burning of amalgam was done using a silver pan and a blow torch connected to electricity.

A retort is a container inverted over a gold amalgam in which the mercury is trapped and heated; volatile mercury travels up through a tube and condenses in an adjacent cooler chamber. More than 95% of the mercury can be recovered through retorting, and this contributes to significant reductions in air pollution and occupational exposure. When amalgam burning is done properly using a retort, very little mercury is lost to the environment, as little as 0.05% (Faird *et al.*, 1991). Other studies by (Shandro et al., 2009; Jønsson *et al.*, 2009) also showed that it is possible to reduce mercury exposure on small scale gold mines sites by using retorts.

A major health concern detected among the participants was that, at the level of mercury exposure and reported frequencies of health problems, majority of them prefer going to pharmacy and chemical shops to buy drugs to treat their ailments instead of seeking medical attention from the hospital in Prestea. These participants probably turn to ignore issues concerning their health, as some of them complained of long hours being spent at the hospital before being attended to; thus affecting their work at the mines. This finding is similar to a study in Suriname where local small scale gold miners rely on self medications, forest medicine and traditional healers to prevent and cure malaria instead of going to the hospital (NIMOS, 2003).

During interviews and education on mercury hazards with the small scale gold miners, most of them have now realized that mercury is of major health concern.

The study sites where the participants worked were widely dispersed with some working in the deep forest, thus making it difficult for this study to randomly sample the participants. Majority of Amazonian studies involving mercury exposure among small scale gold miners have also used cross-sectional designs, with most of them based on convenience sampling due to difficulties also associated with random sampling strategies (Passo, C.J.S and Mergler, D. 2008).

Limitations

Although the participants were staying in communities in Prestea, result of this study cannot be generalized to all the small scale gold miners living in Prestea; because this study did not randomly sample the participants.

The study also did not include a control or non- exposed group for comparison. Signs and symptoms were self reported; and subjective and may be inaccurate.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study indicates that small scale gold miners in Prestea are experiencing mercury exposure in excess of occupational exposure guidelines. Complaints of numbness, metallic tastes, skin rashes and red eyes were mainly observed and reported by participants which might be related to mercury exposure. Though individuals who amalgamate gold were two times more likely to have higher mercury levels in their urine; others who perform activities like sucking of excess mercury for re-use with the mouth are also experiencing mercury exposure.

6.2 Recommendations

Environmental Protection Agency (EPA)

- Should organize training programmes in safety and hazards associated with handling of mercury among small scale gold miners in Prestea to raise their awareness concerning mercury exposure.

- Districts field officers of EPA should regularly monitor and supervise the activities of these small scale gold miners to ensure that the environment is not destroyed through indiscriminate use of mercury.

Prestea Huni-Valley District Health Directorate

- Should regularly organize medical screening for small scale gold miners in Prestea.

Minerals Commission

- Should contract local craft manufacturers to produce retorts at affordable prices for sale to small scale gold miners in Prestea.
- Should identify safe designated areas for these miners especially those working near human settlements in order to minimize environmental degradation as well as human exposure due to mercury use.

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Appendix 1

Subject number: …......................

CONSENT TO PARTICIPATE IN A RESEARCH PROJECT

TITLE OF PROJECT: Exposure of Small scale Gold Miners in Prestea to Mercury, Ghana

Before agreeing to participate in this research study, it is important that you read the following explanation of this study. This statement describes the purpose, procedures, benefits, risks, discomforts, and precautions of the program. Also described are the alternative procedures available to you, as well as your right to withdraw from the study at any time.

Explanation of Procedures

You are being invited to participate in a research project to assess exposure of small scale gold miners in Prestea to mercury. The approach of the research is through the use of a questionnaire and Urine specimen collection. Your urine sample will be sent to the laboratory for mercury testing. You will complete the questionnaire that will require answers on personal profile and factors for mercury exposure (i.e. amalgamation, burning of amalgam, etc.). The duration of the research is one month. After the research your urine sample will be incinerated.

Risks and Discomforts

By participating in this research, you are likely to experience some form of discomfort. This includes the discomfort of questioning and urine specimen collection. The team will try and decrease your chances of these risks from occurring. You will be required to produce one morning urine sample, about 20-50ml.

Benefits

There are no direct benefits by participating in this project. However, this research is expected to provide data on factors for mercury exposure and its adverse health effects. Anyone with high levels of urine Mercury will be referred to the appropriate hospital.

Confidentiality

All information gathered from the study will remain confidential. Your identity as a participant will not be disclosed to any unauthorized persons, only the researchers and Ghana Health Service will have access to the research materials, which will be kept in a locked drawer. Any references to your identity that would compromise your anonymity will be removed.

Withdrawal from Project

Participation in this study is voluntary; refusal to participate will involve no penalty. You are free to withdraw consent and discontinue participation in this project at any time without prejudice from the research team. You are also free not to answer any question.

Costs and/or Payments to Subject for Participation in Research

There will be no costs for participating in the research. Also, you will not be paid to participate in this research project.

Any questions concerning the research project should be directed to Professor E. Afari, School of Public Health (0208131828), Mr Ebenezer Kofi Mensah, School of Public Health (0244528615) and Hannah Frimpong, Administrator Ghana Health Service Ethical Review Committee (0244516482).

Consent to participate in Research

I …..

□ Confirm that I have read the written information (or have had the information read to me) for the study **Exposure of Small scale Gold Miners in Prestea to Mercury, Ghana** and that the study procedures have been explained to me by study staff during the consent process for this study.

□ Confirm that I have had the opportunity to ask questions about this study and I am satisfied with the answers and explanations that have been provided.

□ Understand that I grant access to data to authorised persons described in the information sheet.

□ Have been given time and opportunity to consider taking part in this study.

Tick as appropriate (this decision will not affect your ability to enter the study):

I consent to participate in the above research study.

Signature of Subject: ....

Thumb of subject unable to sign

Date..............................

Signature of Interviewer: ....

Date..............................

Subjects incapable of giving consent

Name of Witness: ……………………………

Signature of Witness: …………………………….

Date..............................

Appendix 2

Subject number: …......................

CONSENT FORM FOR PARENTS AND GUARDIANS

TITLE OF PROJECT: Exposure of Small scale Gold Miners in Prestea to Mercury, Ghana

This statement describes the purpose, procedures, benefits, risks, discomforts, and precautions of the program. Also described are the alternative procedures available to your ward, as well as the right to withdraw from the study at any time.

Explanation of Procedures

Your ward is being invited to participate in a research project to assess exposure of small scale gold miners in Prestea to mercury. The approach of the research is through the use of a questionnaire and Urine specimen collection. Urine sample will be sent to the laboratory for mercury testing. Your ward will complete a questionnaire that will require answers on personal profile and factors for mercury exposure (i.e. amalgamation, burning of amalgam, etc.). The duration of the research is one month. After the research urine sample will be incinerated.

Risks and Discomforts

By participating in this research, your ward is likely to experience some form of discomfort. This includes the discomfort of questioning and urine specimen collection.

The team will try and decrease the chances of these risks from occurring. Your ward will be required to produce one morning urine sample, about 20-50ml.

Benefits

There are no direct benefits in participating in this project. However, this research is expected to provide data on factors for mercury exposure and its adverse health effects. Anyone with high levels of urine Mercury will be referred to the appropriate hospital.

Confidentiality

All information gathered from the study will remain confidential. Your ward's identity as a participant will not be disclosed to any unauthorized persons, only the researchers and Ghana Health Service will have access to the research materials, which will be kept in a locked drawer. Any references to your ward's identity would be removed.

Withdrawal from Project

Participation in this study is voluntary; refusal to participate will involve no penalty. Your ward is free to withdraw consent and discontinue participation in this project at any time without prejudice from the research team.

Costs and/or Payments to Subject for Participation in Research

There will be no costs for participating in the research. Also, your ward will not be paid to participate in this research project.

Any questions concerning the research project should be directed to Professor E. Afari, School of Public Health (0208131828), Mr Ebenezer Kofi Mensah, School of Public Health (0244528615) and Hannah Frimpong, Administrator Ghana Health Service Ethical Review Committee (0244516482).

Consent of Parent/Guardian allowing their ward to participate in the Research

I …..

□ Confirm that I have read the written information (or have had the information read to me) for the study **Exposure of Small scale Gold Miners in Prestea to Mercury, Ghana** and that the study procedures have been explained to me by study staff during the consent process for this study.

□ Confirm that I have had the opportunity to ask questions about this study and I am satisfied with the answers and explanations that have been provided.

Tick as appropriate

I allow my ward to participate in the above research study.

Signature of Parent/Guardian: ....

Date..............................

Thumb of Parent/Guardian unable to sign

Signature of Interviewer: ....

Date..............................

Appendix 3

Exposure Of Small scale Gold Miners In Prestea To Mercury, Ghana

Questionnaire

Subject Number............ Name of site...................... Date..........

A. Personel Profile

A1 Name...

A2 Age...

A3 Gender: (1) Male (2) Female

A4 Educational Level: (1) None (2) Primary (3) Secondary (4) Tertiary

A5 Marital Status: (1) Single (2) Married (3)Divorced (4) Widowed

A6 Ethinicity.......................................

A7 Nationality.....................................

B. Occupational Exposure and Safety

B1 How long have you been working as an informal gold miner? ....Months ....Years

B2 How many days do you work per week?......................days

B3 How many hours do you spent per day at this mine?..................hours

B4 Do you move between mines in a day? (1) Yes (2) No

B5 If yes, how many times (1) 2 times (2) 3 times (3) 4 times (4) more than 4 times

B6 What do you usually do at this site?

(Circle all that apply)

Amagamating with Mercury	1
Burning of Amalgam	2
Smelting of Gold	3
Transporting of Mercury	4
Transporting of ore	5
Standing in pool of water/stream whiles working	6
Sucking excess mercury from the Amalgam for reuse	7

B7 Do you use the following in processing the ore?

	Always	Seldom	Don't use
Rubber aprons	1	2	3
Mercury containers	1	2	3
Face masks	1	2	3
Rubber gloves	1	2	3
Leather boots	1	2	3
Head coverings	1	2	3

B8 Have you worked at the goldsmiths shop before? (1) Yes (2) No

B9 If yes, for how many years......................

B10 Where do you keep mercury?

(1) At home (2) Mine site (3) Do not keep mercury

B11 Do you know the hazards in using mercury? (1) Yes (2) No

B12 Were you working at other mines before coming to Prestea? (1) Yes (2) No

B13 Have you ever receive any training on occupational safety and health? (1) Yes (2) No

B14 If yes, who provided it.(Circle all that apply)

Environmental Protection Agency	1
District Assembly	2
Small Scale Mining Association	3
Formal Minig Companies	4

Others(Specify)...................................

B15 What is your main source of drinking water at this mine?

Bore hole	1
Pipe borne water	2
River/Stream	3

Sachet water 4

B16 Do consumes fish from the Ankobra River? (1) No (2) Yes

B17 Do you have any dental fillings? (1) No (2) Yes

C. Signs and Symptoms of Mercury Exposure

C1 Do you have any of these health problems?

	Yes	No
Red eyes	1	2
Skin rashes	1	2
Frequent cough	1	2
Persistent fever	1	2
Persistent headache	1	2
Metallic taste	1	2
Fatigue	1	2
Muscle aches	1	2
Sinusitis	1	2
Insomnia	1	2
Numbness	1	2
Hair loss	1	2

Others(specify)...

C2 Where do you go when you face health problems?

Pharmacy/ Chemist shop	1
Hospital	2
Traditional Healers	3

D. Measurement

D1 Mercury Level.......................................ug/L

Appendix 4

Reagent preparation

Stannous chloride reductant ($SnCl_2$ 25%w/v)

25grams of Stannous chloride was weighed and dissolved in 100ml of distilled water. The mixture was stirred to ensure that all ingredients had dissolved completely. The mixture was poured into a clean mercury-free plastic bottle and labeled.

Hydrochloric acid solution (HCL 20%v/v)

20ml of Hydrochloric acid was measured and dissolved in 100ml of distilled water. The mixture was poured into a clean mercury free-glass bottle and labeled.

Nitric acid solution (HNO_3 5%v/v)

5ml of Nitric acid was measured and dissolved in 100ml of distilled water. The mixture was poured into a clean mercury free-glass bottle and labeled.

Preparation of 500ml each of working standard solutions of 10ug/L, 20ug/L and 50ug/L of mercury from a stock mercury standard of 1000ppm in 0.5M Nitric acid.

For the 10ug/L working standard, 5ul was pipetted with an automatic pipette into a mercury- free measuring cylinder and topped up to the 500 mark with distilled water.

For the 20ug/L working standard, 10ul was pipetted with an automatic pipette into a mercury- free measuring cylinder and topped up to the 500 mark with distilled water.

For the 50ug/L working standard, 25ul was pipetted with an automatic pipette into a mercury- free measuring cylinder and topped up to the 500 mark with distilled water.

All the working standards were poured into a mercury-free plastic bottle and labeled.

Appendix 5

LABORATORY RESULTS OF MERCURY IN URINE

Subject No.	Mercury Result (µg/L)	Subject No.	Mercury Result (µg /L)
1	5.01	36	3.50
2	0.01	37	6.46
3	0.01	38	6.58
4	1.17	39	25.44
5	5.01	40	2.93
6	0.01	41	9.47
7	0.01	42	0.01
8	2.30	43	20.23
9	4.26	44	0.01
10	2.30	45	12.52
11	3.07	46	20.18
12	3.70	47	3.18
13	1.91	48	25.09
14	2.02	49	40.26
15	3.11	50	1.84
16	2.58	51	0.01
17	16.79	52	32.31
18	2.11	53	33.13
19	0.01	54	48.14
20	16.42	55	49.19
21	0.01	56	0.01
22	4.11	57	2.05
23	16.74	58	5.96
24	3.25	59	4.83
25	0.01	60	4.72
26	12.04	61	5.85
27	1.09	62	18.52
28	0.01	63	3.11
29	27.75	64	2.23
30	33.89	65	4.57
31	8.59	66	3.27
32	5.02	67	2.26
33	25.24	68	1.98
34	5.00	69	2.31
35	8.86	70	4.78

71	3.40
72	4.07
73	1.17
74	1.84
75	7.84
76	11.62
77	9.13
78	6.48
79	7.71
80	1.25
81	2.05
82	5.44
83	2.65
84	2.37
85	3.97
86	4.44
87	0.76
88	0.01
89	2.92
90	3.42
91	4.24
92	3.10
93	6.07
94	2.17
95	4.31
96	4.81
97	5.75
98	4.87
99	5.28
100	0.01
101	1.70
102	2.01
103	2.01
104	16.25
105	37.73
106	42.02
107	36.93
108	32.37
109	0.68
110	7.99

111	5.39
112	2.94
113	1.12
114	5.55
115	2.09
116	1.11
117	3.44
118	7.95
119	8.86
120	9.03
121	29.83
122	6.46
123	3.64
124	2.79
125	1.53
126	3.96
127	4.72
128	1.77
129	3.37
130	13.89
131	19.00
132	16.71
133	21.12
134	23.08
135	18.02
136	31.59
137	37.86
138	0.01
139	8.10
140	12.96
141	15.09
142	10.22
143	13.47
144	0.08
145	0.01
146	0.01
147	0.01
148	0.27
149	3.64
150	0.01

151	0.01
152	0.01
153	0.01
154	5.39
155	0.65
156	0.91
157	4.92
158	5.16
159	2.40
160	3.53
161	9.18
162	6.30
163	5.41
164	3.91
165	3.62
166	6.23
167	6.03
168	4.15
169	3.51
170	5.01
171	4.59
172	11.22
173	12.92
174	15.61
175	14.69
176	17.58
177	3.66
178	9.95
179	7.77
180	4.85
181	4.53
182	4.59
183	4.94
184	10.56
185	12.34
186	6.06
187	11.51
188	15.40
189	1.10
190	1.72

191	4.30
192	7.37
193	1.38
194	1.33
195	4.45
196	6.57
197	3.51
198	7.23
199	6.20
200	6.41
201	5.93
202	20.80
203	10.29
204	6.35
205	7.45
206	6.02
207	2.04
208	0.96
209	2.74
210	2.90
211	1.17
212	1.57
213	1.89
214	2.62
215	1.82
216	4.38
217	1.45
218	7.40
219	5.87
220	4.29
221	1.15
222	11.57
223	4.49
224	0.01
225	0.01
226	0.01
227	0.01
228	3.09
229	3.17
230	5.72

231	3.02
232	1.43
233	3.08
234	2.80
235	3.15
236	3.36
237	4.06
238	8.03
239	5.62
240	2.79
241	2.18
242	0.84
243	1.10
244	1.22
245	1.73
246	1.55
247	1.40
248	1.14
249	2.97
250	4.97
251	4.15
252	3.40
253	3.41
254	2.71
255	2.43
256	4.68
257	6.77
258	4.67
259	4.50
260	1.75
261	5.91
262	4.60
263	18.62
264	8.25
265	6.12
266	6.44
267	19.75
268	22.22
269	8.08
270	4.52

271	3.90
272	1.94
273	4.72
274	1.52
275	3.89
276	11.22
277	1.84
278	3.56
279	5.57
280	2.58
281	20.40
282	8.05
283	10.61
284	37.18
285	4.10
286	16.95
287	23.57
288	15.95
289	16.50
290	21.93
291	23.13
292	25.34
293	1.37
294	42.88
295	13.37
296	9.86
297	24.13
298	12.07
299	6.21
300	5.96
301	10.71
302	13.54
303	6.15
304	9.35
305	10.78
306	8.46
307	1.42
308	2.29
309	3.01
310	10.66

311	12.02
312	16.86
313	20.15
314	17.25
315	21.14
316	4.62
317	1.32
318	4.45
319	4.71
320	13.88
321	15.28
322	13.57
323	50.50
324	2.41
325	9.80
326	10.82
327	5.92

328	3.66
329	28.93
330	10.48
331	7.39
332	2.32
333	32.98
334	10.22
335	13.87
336	0.01
337	0.01
338	26.19
339	0.01
340	27.78
341	18.17
342	14.82
343	12.08