UNACOH/NAPE/ MGLSD (OHS) / Diálogos

MERCURY (HG) FREE GOLD MINING PROJECT: 2017 – 20

(Collaboration between Uganda and Denmark)

ASSESSMENT OF OCCUPATIONAL, ENVIRONMENT AND OTHER IMPACTS FROM USE OF MERCURY IN ARTISANAL SMALL – SCALE GOLD MINING (ASGM) IN UGANDA: 2017 – 2018

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ACRONYMS AND ABBREVIATIONS

The terms, acronyms and abbreviations below may appear in this document.

µg	microgram (10-6 gram);
µg/kg	micrograms per kilogram body weight per day; units used for describing intakes (or doses) of mercury such as intakes that are considered safe for humans. In some cases the time unit weeks is also used;
AAS	Atomic absorption spectrometry;
ASGM	Artisanal and Small-Scale Gold Miners;
FAO	Food and Agriculture Organization of the United Nations;
FDA	Food and Drug Administration (in the USA);
GEMS/Food	Global Environment Monitoring System / Food Contamination Monitoring and Assessment Programme;
HBM	Human Bio-Monitoring;
Hg	mercury;
Hg0	elemental mercury;
Hg(II) or Hg^2 or Hg^{2+}	- Divalent mercury - the dominating mercury form in organic and inorganic mercury compounds. In the atmosphere, mercury species with divalent mercury are more easily washed out of the air with precipitation and deposited than elemental mercury;
IPCS	International Programme on Chemical Safety;
JECFA	Joint FAO/WHO Expert Committee on Food Additives;
LC50	Lethal Concentration, 50%; concentration of toxic substance in a medium (for example water) at which 50% of the individuals in the toxicity test sample die; a unit used to describe the level of toxicity of a substance to a specific species, for example fish;
LOAEL	Lowest Observed Adverse Effect Level -see LOEL-;
LOEL	Lowest Observed Effect Level (also called LOAEL – lowest observed adverse effect level); for toxic or other effects imposed on organisms or experienced by humans;
mg	milligram (10-3 gram);
MeHg	Methylmercury;
MS	Mass Spectrometry;
MRL	Minimum Risk Level; term used in evaluation of risk of toxic effects from various chemicals (such as methylmercury) on humans; the MRL is defined by US ATSDR as an estimate of the level of human exposure to a chemical that does not entail appreciable risk of adverse non-cancer health effects;

NOEL	No Observed Effect Level (also called NOAEL – no observed adverse effect level); for toxic or other effects imposed on organisms or experienced by humans;
NOEL/BMDL	No Observed Effect Level/Benchmark Dose Level;
ppb	parts per billion;
ppm	parts per million;
ppt	parts per trillion;
RfC	Reference Concentration;
RfD	Reference Dose; term used in evaluation of risk of toxic effects various chemicals (such as methylmercury) on humans; the RfD (or RfC) is defined by US EPA as an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime;
SAICM	Strategic Approach to International Chemicals Management;
US EPA	Environmental Protection Agency of the United States of America;
WHO	World Health Organization.

TERMS & DEFINITIONS

Bioaccumulation - *the increase in concentration of a substance(s) in an organism or a part of that organism or ecosystem.*

Bioconcentration and bioaccumulation *- occur within an organism, and*

Biomagnification *- occurs across trophic (food chain) levels.)*

Biomagnification (also called Bioamplification) *- the increase in concentration of a substance in a food chain, not an organism.*

Biomarker - *a naturally occurring molecule, gene, or characteristic by which a particular pathological or physiological process, disease, etc. can be identified.*

Biomonitoring *- the measurement of the body burden of toxic chemical compounds, elements, or their metabolites, in biological substances. Often, these measurements are done in blood and urine.*

Biomonitoring - *measurements of pollutants and/or their metabolites, also known as biological markers (or biomarkers)*

Biomonitoring *- the assessment of human exposure to environmental chemicals by measuring the chemicals or their metabolites in human blood, urine, saliva, or tissue. The results of such measurement are usually called "body burden." Nearly all of us carry a body burden of chemicals that sometimes is sufficiently.*

Biosafety *– the application of knowledge, techniques and equipment to prevent personal, laboratory or environmental exposure to potentially infectious agents or biohazards.*

Biosecurity - *the protection, control and accountability measures implemented to prevent the loss, theft, misuse, diversion, unauthorized access, retention, transfer or intentional release of biological agents and toxins and related resources;*

Human biomonitoring *- a method for assessing human exposure to chemicals (or their associated effects) by measuring these chemicals, their metabolites, or reaction products in human tissues or specimens such as blood, urine or hair'.*

Environmental biomonitoring - *the use of biological responses to assess changes in the* ***environment*** *changes due to human or anthropogenic causes.* ***Biomonitoring programs*** *may be qualitative, semi-quantitative, or quantitative.*

Biotransformation - *chemical alteration of chemicals such as nutrients, amino acids, toxins, and drugs in the body. It is also needed to render non-polar compounds polar so that they are not reabsorbed in renal tubules and are excreted.*

Biotransformation *- the transformation of chemical compounds within a living system*

Harm - *generally describes the direct or indirect degradation, temporary or permanent, of the physical, mental, or social wellbeing of a worker.*

Hazard - *something that can cause harm if not controlled*

Environment - *Land, air, water and living organisms surrounding human life, including physical, biological or chemical elements of any of the above.*

Exposure assessment *- the process of estimating or measuring the magnitude, frequency and duration of exposure to an agent, along with the number and characteristics of the population exposed. Ideally, it describes the sources, pathways, routes, and the uncertainties in the assessment.*

Exposure assessment *- the extent, duration, frequency and magnitude of exposures to a pollutant (or multiple pollutants) are estimated via various routes (ingestion, inhalation, dermal or* transplacental */in utero exposure) for individuals or populations. Exposures can be estimated by measuring pollutant levels in various body tissues (such as hair, blood, urine, or nails) as biomarkers or by using various mathematical models along with input data (such as facility release information, fish mercury levels, dietary patterns, etc.).*

Occupational accident - *an occurrence arising out of, or in the course of work which, results in fatal or non-fatal injury.*

Occupational disease - *a disease contracted as a result of an exposure to risk factors arising from work activity.*

Occupational injury *- any personal injury resulting from an occupational accident.*

Outcome - *the outcome is the harm that results from an uncontrolled hazard*

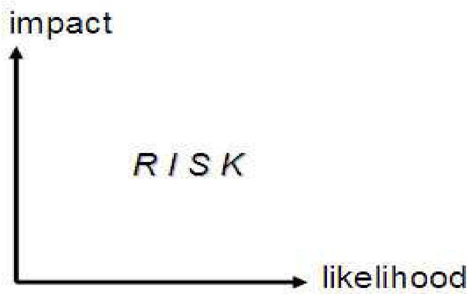
Residue *- a residue of substances having a pharmacological action, or their metabolites and of other substances transmitted to animal products and likely to be harmful to human health;*

Risk *- a function of the probability of an adverse effect and the magnitude of that effect, consequential to a hazard(s) in food.*

Risk - *acombination of the probability that aparticular outcome will occur and the severity of the harm is involved*

$$\textbf{Risk} = C \times \text{Hazard} \times \text{Exposure}$$

$$\textbf{Risk} = \frac{\text{Hazard x Vulnerability}}{\text{Manageability}}$$



***Risk** can be expressed numerically (e.g. a 0.5 or 50/50 chance of the outcome occurring during a year), in relative terms (e.g. high/medium/low), or with a multi – diamentsional classification scheme (e.g. Situation - specific risks)*

***Risk assessment** - a scientifically based process consisting of the following steps (i) hazard identification, (ii) hazard characterization, (iii) exposure assessment, and*
(iv) Risk characterization.

***Risk assessment** - A human health risk assessment for chemicals is generally a study to estimate the likelihood of adverse health effects occurring in an individual, subpopulation or population due to exposure to some chemical (such as mercury).*

***Risk analysis** - a process consisting of three components: risk assessment, risk management and risk communication.*

***Sample** - One or more units selected from a population of units, or a portion of material selected from a larger quantity of material. For the purposes of these recommendations, a representative sample is intended to be representative of the lot, the bulk sample, the animal, etc., in respect of its pesticide residue content and not necessarily in respect of other attributes.*

***Sampling** - The procedure used to draw and constitute a sample. Empirical or punctual sampling procedures are sampling procedures, which are not statistical-based procedures that are used to make a decision on the inspected lot.*

***Sampling error** - Part of the total estimation error due to one or several of the following parameters:*
the heterogeneity of the inspected characteristics,
the random nature of a sampling,
the known and acceptable characteristics of the sampling plans.

***Sampling plan** - Planned procedure which enables one to choose, or draw separate samples from a lot, in order to get the information needed, such as a decision on compliance status of the lot. More precisely, a sampling plan is a scheme defining the number of items to collect and the number of non-confirming items required in a sample to evaluate the compliance status of a lot.*

***Sample size** - The number of units, or quantity of material, constituting the sample.*

EXECUTIVE SUMMARY

Background

With the gold rush in Uganda communities are continuously becoming artisanal small scale miners. There was therefore, a need to carry out a baseline study, including human and ecosystem bio-monitoring, for occupational health, safety and environment (OHS&E) impacts from Artisanal Small Scale Gold Mining (ASGM) to establish the level of mercury poisoning to miners, of environmental pollution and degradation as a results of ASGM activities in the country, and to inform future interventions aimed at ensuring sustainable gold production while protecting the health of artisanal small scale gold miners and the environment.

Purpose

The purpose of this study was to provide information on the magnitude of OHS&E impacts related to ASGM in Uganda.

Problem statements

1. What is the level of mercury poisoning in gold miners as indicated by clinical and human bio-monitoring assessments?
2. What are the main sources of exposures, Occupational or environmental (diet, polluted water sources, etc)?
3. What is the level of ASGM organization and capacity (human, equipment, infrastructure, funds, etc)
4. What is the level of the miners KAP of OHS&E?
5. Assessment of the magnitude of related socio – economic impacts.

Study objectives

1. To assess the extent of mercury (and other chemicals) use, environmental contamination/ pollution, exposure and poisoning among ASGMs in Uganda.
2. To assess the other occupational hazards faced by ASGMs in Uganda.
3. To determine the existing organisational structures of ASGMs and establish how local and national politics impacts on ASGM.
4. To establish gender, health, safety, enviromental factors affecting ASGMs in Uganda n Uganda

Research Questions, Hypothesis

(a) What is the magnitude (level) of mercury exposure and poisoning in gold miners in Uganda?
(b) What is the current level of Hg pollution of environmental ecosystems in Uganda?

Study design

This was a cross-sectional study employing both qualitative and quantitative methods. The assessment included key informant interviews, structured interviewer administered interviews, observations as well as conducting human and ecological bio-monitoring.

Study area and population

The study was conducted in districts with active ASGMs in the 4 different regions where gold deposits are found in the country namely Bugiri, Namayingo and Busia in the eastern region where some mining sites in this area are located close to the shores of Lake Victoria), Mubende in the Central region, Buhweju, Bushenyi and Ibanda in the Western region, Nakapiripiriti, Amudat and Moroto in the Karamojong Sub- Region. The study population included artisanal small scale gold miners located in the above mentioned districts. These small scale gold miners often use low technology and machinery in gold mining.

Study participants.

Study participants were selected from Small - scale artisanal gold miners at 2 mining sites in the different regions in Uganda. Key informants included district officials responsible for livelihoods, health, safety and environment of the communities.

Sampling plan

Activities included determination of the sample size, and procedure, study variables, development and pre-testing of data collection tools and procedures, training of Research Assistants, data management, qualitative and quantitave data analysis, instituting Bio-safety and bio-security measures and Ethical Considerations

Human Bio-monitoring

Human Bio-monitoring included medical evaluations and health exposure assessment and bio – monitoring using blood and urine samples. With regard to the sampling plan and sampling procedure for biomarker data, 40 participants were randomly selected from the 160 participants and included in the health assessment. A total of 40 samples of blood and 40 samples of urine (10 samples of each per region) were collected). All sample collection, packaging, storage, transportation, etc, was based on the *WHO/UNEP Protocols for Sample Collection Procedures for Urine and Blood.*

Environmental ecosystems monitoring

A total of 64 samples (4 samples per district) from environment ecosystems (water, sediment, soil, plants, and fish) were collected by the environmentalist member of the study team, stored and transported to the Directorate of Government Analytical Laboratory (DGAL) in Wandegeya based on an ecosystem sampling plan.

Laboratory analysis

Laboratory analysis focused on the presence and levels of Total Mercury, Hg (Mean- Value Mercury level). The Directorate of Government Analytical laboratories (DGAL), Ministry of Internal Affairs carried out all bio – monitoring sample analysis (human samples, selected food crops, water and sediment analysis and residue analysis). Testing for heavy metals like Mercury was done using Atomic Absorption Spectrometry.

Results

Socio – demographic characteristics

Females and children are among the most vulnerable sub- populations in the mining sector. The highest number of female miners was recorded in the Karamoja region (50.98%) followed by Eastern region (25.49%, Central region at 20.00% and Western region at 7.69%. In general, the level of child labour was low, which was attributed the on – going government efforts to enforce compliance to laws prohibiting child labour. Low level of education is considered an occupational risk factor. Respondents who had not attended school were highest in the Karamoja region (20.00%), Eastern region (12.00%), Western region (5.13%) and Central region (0%). Most miners had attended primary level of education with the Karamoja region (52.00%), Western region (56.44%), Central region (48.72%) and Eastern region (38.00%).

Use of mercury and other chemicals

Mercury was mostly in the districts of Karamoja and Eastern regions (100), Central region 73.68%; Western region 41.18%; with a total average of 80.52%. Use of Cyanide was mainly reported in the Central region: 28.21%; Eastern region 4.55%; Karamoja sub -region 0%; Western region 0%; with a total average of 13.68%. Borax: Central region 2.56%; Karamoja sub -region 0%; Eastern region 0%; Western region 0%; with a total average of 1.05%. Lime: Karamoja sub -region 0%; Eastern region 0%; Western region 0%; Central region 0%; with a total average of 0%. Zinc: Karamoja sub -region 0%; Eastern region 0%; Western region 0%; Central region 0%; with a total average of 0%.

Occupational exposure to mercury

Assessment for Occupational exposure to mercury revealed that many Miners had ever worked with mercury in all the study regions, with Eastern region at 88.24 %; Karamoja sub –region: 86.27 %; Central region: 72.50 % Western region: 36.84%. Average duration of exposure (Mean Standard Deviation) was reported as follows: Eastern region: 9.97, SD ±7.60; Karamoja sub –region: 3.59, SD ± 3.0**;** Central region: 2.45, SD ± 1.67; Western region: 1.02 SD± 0.89.

Occupational hazards

The study teams observed that occupational hazards in this sector were mainly physical (noise, vibration, heat, limited lighting while digging tunnels), Chemicals and toxic agents (mainly exoposure to mercury, dust, fumes from burning amalgam, Ergonomic (Lifting heavy loads, fatigue, abnormal postures) and Psyco- social (stress, working long hours). Biological hazards were mot a major issue. With regard to safe work practices; the use of PPEs was very limited with only 24.16% reporting that they use PPEs and even the their adequacy , efficiency and appropriateness were wanting. The level of awareness of occupational health and safety practices was also low at 41.34%. Another challenge is the low technology or no technology used in the mining. Most of the mining is based on unskilled labour.

Health effects associated with exposure to mercury

Various symptoms associated with mercury exposure and poisoning were recorded during health assessment of respondents. Symptoms which were statistically significant following adjusting of known confounding factors included shaking of hands(Odds Ratio 24.09,95% Confidence Interval 1.71 to 338.74), eye problems (10.97,1.97 to 62.48),chest pain (9.02,3.31 to 24.60), numbness (8.51,2.11 to 34.36),back pain (6.21,2.20 to 17.50),fatigue and stress(5.38,1.94 to 14.88),headache(4.67,1.93 to 11.28),dizziness(3.84,1.52 to 9.74) joint pain(3.23, 1.26 to 8.33) and respiratory problems(3.18,1.01 to 10.12).

A statistically significant difference in median mercury blood levels in the different regions was observed. Mubende district had the highest median blood levels of mercury (136µg/l) relative to Busia (60µg/l), Ibanda(43µg/l)and Amudat(less than 0.001ug/l). The Kruskal-Wallis equality-of-populations rank test indicated a statistically significant difference in median mercury blood levels in the different regions (chi square value x^2= 15.147, df=2 and p value =0.0005).

Similarly, Mubende district had the highest median urine levels of mercury (105.5µg/l) relative to Busia (70.6 µg/l),Ibanda(58 µg/l)and Amudat(less than 0.001ug/l).Using the Kruskal Wallis test there was a statistically significant difference in the median mercury urine levels in the different regions(chi square value x^2= 11.664,df=2 and p value =0.0029) This was largely attributed to the practice of mercury use, where for example, is a major practice in Mubende and Busia districts.

With regard to association between mercury levels and socio-economic and occupational health related variables, statistically significant differences were obtained between mercury levels in urine across gender, type of work and knowledge in Occupational Health and Safety Practices. Males had a lower median level of mercury in urine (65.4 µg/l) compared to females (84.7µg/l). There was a difference of -66(95% C1: -103.4 to -51.5) p value of 0.0476 which is less than 0.05 which was statistically significant. We therefore concluded that there is a difference in mercury levels in urine between males and females. Panners had the highest mercury levels in urine (109µg/l) compared to burners (90.6µg/l) and extractors (62.9µg/l). This observed difference was statistically significant with chi square value of 9.595,df2 and p vale of 0.0083 which is less than 0.05. We therefore concluded that there is a difference in mercury levels in urine between extractors, panners and burners.

Those with knowledge in occupational health practices had higher median levels of mercury in blood and urine (119.5µg/l and 95. 6 µg/l, respectively) and those without (52.25µg/l and 65.4µg/l respectively). The median difference in blood mercury levels for those with and without knowledge in OSH practices was -66(95% CI: -102.4 to -51.5) with a p-value of 0.0129 which is less than 0.05.While the median difference in urine mercury levels for those with and without knowledge in OSH practices was -69(95% CI: -72 to -61.8) with a p-value of 0.0280 which is less than 0.05.This indicates statistically significant differences in both mercury blood and urine levels between those with knowledge in occupational health practices and those without.

Environment pollution and degradation

Major issues of concern which were noted in all the mining districts included miners mismanaging of chemical spills resulting in contaminated ecosystems especially wetlands, pollution of water sources and threatening aquatic life, cutting down indiscriminately all trees as a result there is substantial deforestation, digging and leave soil, sand and stones everywhere encouraging soil erosion and not covering or restoring the dug pits.

Ecosystem analytical results indicated that in a median level mercury in water of 31µg/l, 13µg/l,11µg/l and less than 0.001µg/l in Busia, Ibanda ,Mubende and Amudat respectively. Median levels of mercury in soil samples were 0.082µg/l, 0.258µg/l, 0.256µg/l and less than 0.001µg/l in Busia, Ibanda, Mubende and Amudat districts respectively. In Ibanda district some levels of mercury were detected although mercury use is limited. This may be attributed to environmental pollution from other sources.

Mercury exposure from in comsumption of contaminated food

The decision for the diagnosis of possible exceedence of chronic mercury threshold limits for mercury is made based on Reference levels for daily or weekly methyl mercury or mercury intakes by the FAO/WHO Codex Alimentarius Commission.

- Total methyl mercury concentration Recommended level: 0.5mg/kg (Codex guideline)
- Intake levels for methyl mercury exposures range from 0.7 to 2 µg methyl mercury per kilogram body weight (µg/kg body weight) per week.

However, fish consumption by these mining communities is not regular and the quantities consumed are small. It was therefore, not possible to make realistic estimates for methylmercury intake from fish consumption. It should also be noted Uganda does not have a National Food Consumption patterns database which is crucial for conducting chemical exposure assessments in food.

Conclusion

In the last decade Uganda has experienced an increase of ASGM and use of mercury with adverse OHS&E and other related socio –economic impacts as demonstrated by findings from human and bio -monitoring studies conducted in this study.

Recommendations

Policy & regulatory framework

(1) Government should, as a matter of urgency, organize and legalize the ASGM sector, with priority given to the local communities
(2) Government should fast – track support to the sector, regulate, supervise, and license the ASGMs.
(3) There is need to urgently address related environmental degradation
(4) Enable the district and ASGMs to get value for money from the gold mining activities
(5) Enforce compliance to and ensure environmental protection requirements including Environmental Impact Assessments (EIAs)
(6) Establish and implement OHS&E inspection and monitoring programmes at all levels of governance in the district.
(7) Close the mines in some areas which are at highest risk

(8) Enforce phasing out the use of mercury and promote use of alternative chemicals and technologies

Institutional arrangements

(1) The ASGMs should form associations to ease their management and support
(2) Encourage involvement of licensed companies from whom the districts can collect taxes

Awareness & sensitization of stakeholders

(1) Strengthen sensitization and awareness on OHS&E hazards, prevention and control measures in ASGM activities
(2) Promote use of PPEs
(3) Support communities to access and use better mining tools & technologies.

1.0 INTRODUCTION

The Baseline Study for Occupational health, Safety and Environmental (OHS&E) Impacts from Artisanal Small – Scale Gold Mining (ASGM) in Uganda: 2017 – 2018 was a collaboration between national and international implementing Partners namely; Uganda National Association of Community and Occupational Health (UNACOH), National Association of Professional Environmentalists (NAPE), Ministry of Gender, Labour and Social Development- Occupational Safety & Health Department, Ministry of Energy & Mineral Development - Commissioner Mines Department, Districts where ASGM is carried out and DIÁLOGOS - the Danish organization.

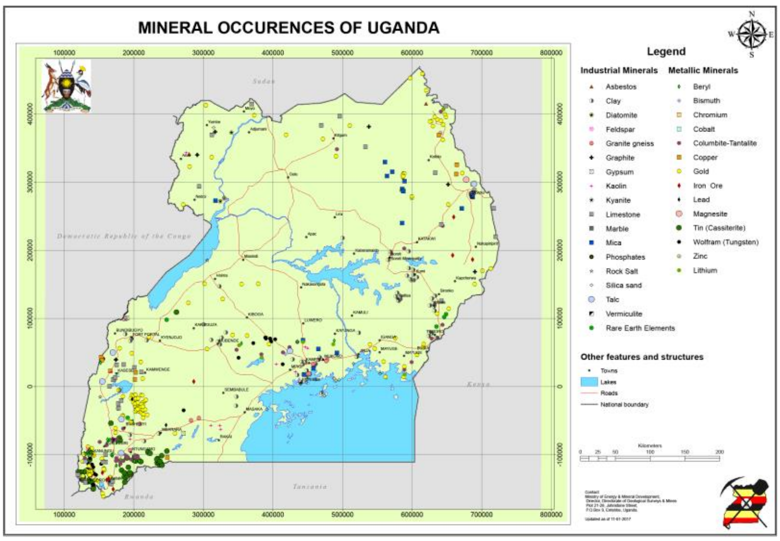
1.1 Background

Mercury has been used by Artisanal Small-Scale Gold Miners (ASGMs) worldwide for hundreds of years to extract gold from refined ore. 'Whole-ore amalgamation' is more widely used and ASGM is now recognized as the single largest contributor to global mercury pollution. The United Nations Environment Programme (UNEP) estimated in 2014 that ASGM contributes a 37% share of the man-made emission of mercury to the atmosphere. About 20 **gram of mercury is used to produce 1 gram of gold** with 'whole-ore-amalgamation'. Non-mercury alternatives are available, better and can post a higher gold recovery. However, the practice of using mercury persists due to many factors, such as the cheap and available supply of mercury, miner habits and misperceptions, and a lack of information on consequences and possible alternatives.

1.2. Gold Mining in Uganda

Gold deposits in Uganda are estimated over 208 square kilometres (especially in districts of Mubende, Amudat, Nkapiripirit, Moroto, Bugiri, Busia, Namayingo, Buhweju, Bushenyi and Ibanda. Figure 1 shows mineral occurrences in Uganda including gold sites, in gold colour. Current gold rush has resulted in an increase in ASGM activities. The numbers of gold miners have reached at least 250,000 (source: Mining experts call for regulations in Uganda's: *gold rush - afkinsider.com*) and ASGM provides a source of livelihood for nearly 500,000 people (including women, children– vulnerable sub-populations).

Figure 1: Mineral Occurrence in Uganda



ASG Miners are often exposed to adverse health, safety and living conditions, often practice extremely inefficient and unsafe methods of "prospecting and extraction" (URA, 2003). The use of mercury in gold processing therefore has resulted in increased occupational health and several environmental risks in this sector. Table 1 shows the geographical distribution of ASGMs in the country.

Table 1: Geographical distribution of ASGMs

No.	Region	District	Active ASGM Sites/District
1	Western	Rubirizi (Buhweju)	• Bihanga • Nyakaziba • Engaju • Kashenyi • Bitsya • Nyakishana
		Bushenyi	2
		Ibanda	• Kicuzi • Rukiri
2	Central	Mubende	• Kanyonza • Lubali • Kitumbi
3	Eastern	Bugiri	• Budde • Nabwaara
		Namayingo	• Buheere • Seguru
		Busia	• Tiira • Syanyonjo • Amonkakire • Mayeero
4	Karamoja	Nakapiriiprit	• Koponi • Somaria • Mourwakinati • Nopochoret • Acherere • Chololo
		Amudat	• Chepkarata • Cheputakolo • other 2 ones
		Moroto	• Rupa • Nangolopus • Nakabate • Nakiroro
Total			**35**

2.0 RISK ASSESSMENT

A human health risk assessment for chemicals is generally a study to estimate the likelihood of adverse health effects occurring in an individual, subpopulation or population due to exposure to some chemical (such as mercury). Risk assessment consists of four main steps: 1) hazard identification; 2) hazard characterization, including dose-response assessment; 3) exposure assessment; and, 4) risk characterization.

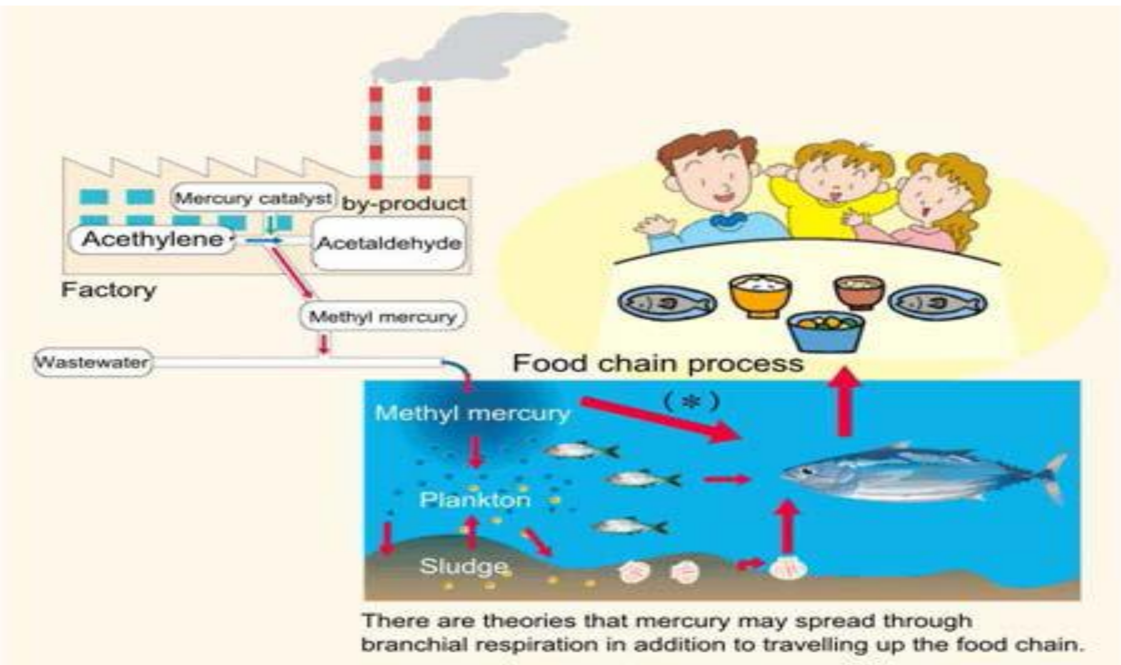
In an exposure assessment, the extent, duration, frequency and magnitude of exposures to a pollutant (or multiple pollutants) are estimated via various routes (ingestion, inhalation, dermal or transplacental /in utero exposure) for individuals or populations. Exposures can be estimated by measuring pollutant levels in various body tissues (such as hair, blood, urine, or nails) as biomarkers or by using various mathematical models along with input data (such as facility release information, fish mercury levels, dietary patterns, etc.).

Human exposure can also be estimated through biomonitoring of levels of mercury in various foods obtained from selected environmental ecosystems, and the consumption patterns by the target communities of, for example, fish.

2.1 Routes of exposure

Mercury is a toxic, persistent pollutant that bio-accumulates, biomagnifies and bio-transforms through the food webs, especially in the aquatic ecosystem. People are exposed to methyl mercury mainly through their diet, especially through the consumption of freshwater and marine fish, and consumption of other animals that consume fish (such as marine mammals).

Figure 2: The Route of Methyl Mercury



Source: Ministry of the Environment Japan

People may be exposed to elemental or inorganic mercury through inhalation of ambient air during occupational activities, from dental amalgams and use of mercury containing beauty products.

2.2 Occupational exposure

Occupational exposure can occur where mercury or mercury compounds are produced, used in processes, or incorporated in products. Occupational exposures have been reported from (among others) chlor-alkali plants, mercury mines, mercury-based small-scale gold and silver mining, refineries, thermometer and sphygmomanometer factories, dental clinics with poor mercury handling practices, and production of mercury-based chemicals. Exposures to elemental mercury or inorganic mercury forms can also occur due to use of some skin-lightening creams and soaps, the presence of mercury in some traditional medicines, use of mercury in cultural practices, and due to various accidental mercury spills in homes, schools or other locations.

2.3 Health effects

The primary targets for toxicity of mercury and mercury compounds are the nervous system, the kidneys, and the cardiovascular system. Developing organ systems (such as the foetal nervous system) are the most sensitive to toxic effects of mercury. Foetal brain mercury levels appear to be significantly higher than in maternal blood and the developing central nervous system of the foetus is currently regarded as the main system of concern as it demonstrates the greatest sensitivity. Other systems include the respiratory, gastrointestinal, hematologic, immune, and reproductive systems. Effects on the nervous system the most sensitive toxicological endpoint observed following exposure to elemental mercury and methyl mercury, because it fat soluble and easily crosses the *Blood- Brain – Barrier*, hence more toxic. While damage to the kidneys is the key end-point in exposure to inorganic mercury compounds.

2.4 Predisposing factors

These include the chemical form of mercury; the dose; the age or developmental stage of the person exposed (the fetus is considered to be the most susceptible); the duration of exposure; and, the route of exposure (inhalation, ingestion, and dermal contact). Dietary patterns can increase exposure to a fish-eating population when fish and seafood are contaminated with mercury.

2.5 Susceptible populations

Generally there are two susceptible subpopulations, namely, those who are more sensitive to the effects of mercury and those who are exposed to higher levels of mercury, for example workers with high occupational exposure such as ASG Miners. Individuals with diseases of the liver, kidney, nervous system, and lung are also at higher risk of suffering from the toxic effects of mercury.

3.0 LITERATURE REVIEW

3.1 Studies in Uganda

3.1.1 Qualitative studies

An Exploratory study on Socio-economic, Health and Environment Management status among Artisanal Small-Scale Gold Miners in Uganda was conducted in 2017 by UNACOH, NAPE and MOGLSD-OSH Dept. However, human exposure assessment (medical evaluations, bio – monitoring was not done.

Objective of the study

The main objective was to explore the socio-economic, health and environment management status among the Artisanal Small-Scale Gold Miners in order to inform project planning.

Specific Objectives

1. To describe the socio-economic, health and safety status and environment management practices among artisanal small-scale gold miners in Namayingo and Mubende District.
2. To explore the use of mercury and its effects among the Artisanal Small-Scale Gold Miners in Namayingo and Mubende District.
3. To identify the existing governance structures for Artisanal Small-Scale Gold Mining in Uganda.

Methodology

This was an exploratory study that utilised qualitative methods conducted in mining sites Mubende and Namayingo districts among small scale artisanal miners. Key informant interviews with local leaders and Focus group discussions with female, male and youth small scale artisanal miners were conducted. Saturation was reached after 6 focus group discussions and 12 key informant interviews.

Results

Overall, there were slightly more (55.93%) female participants compared to males with average age of 32.5 years. Artisanal small scale gold mining was the main source of income for most(68.96%) of the respondents. The monthly income of the respondents ranged between 25,000-10,000,000 Uganda shillings. Majority (58.62%) of respondents indicated poor housing conditions houses made of temporary materials. Respondents reported various health problems including sanitation and water related problems, sexual and reproductive health problems and needs, respiratory tract infections, occupational health related diseases, injuries, and other infectious diseases. Access and availability of health services was limited in the mining communities.

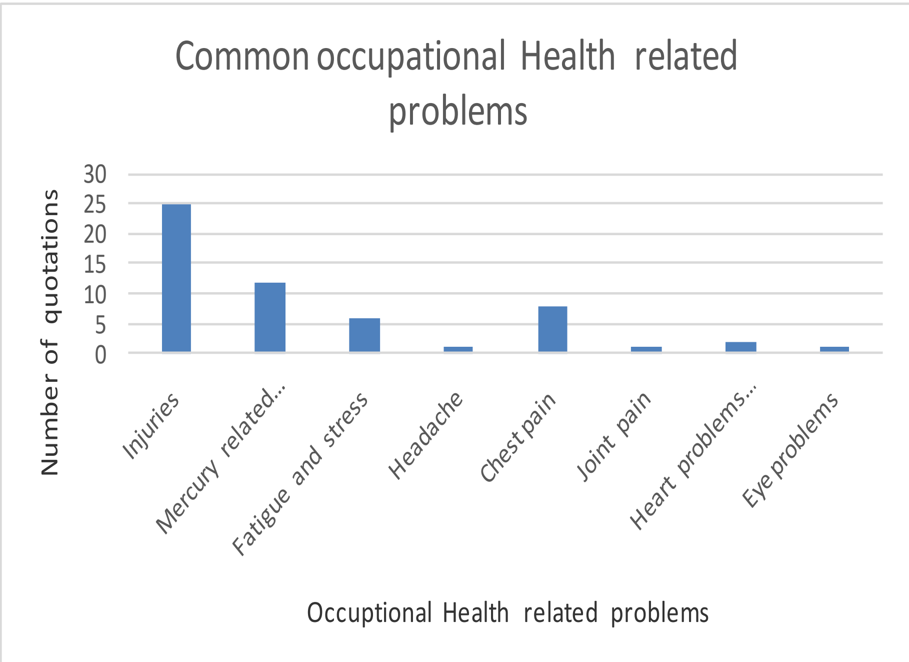
There were no environment practices being practiced. Mercury was the commonest chemical used in gold mining process. This was commonly obtained from gold buyers at a cost between Ug.500, 000/= ($140) and Ug.700, 000/= ($195) per kg. Miners indicated they had observed someone affected by mercury with the following characteristics sore feet (perceived as holes in the feet by miners), swollen legs, numbness of hands and feet, uncontrolled shaking of hands, Dizziness, headache, and poor memory.

Some respondents indicated being organized in groups. Functions of groups included save and loan money though they still help members to get licenses for operation, help members solve their individual problems/needs, help in procuring machinery and developing members in other businesses.

Occupational health related diseases and problems

Respondents experience various occupational health related problems including injuries, mercury related effects on the body, fatigue and stress, headaches, chest pain, heart problems and elevated blood pressure and eye problems. The most mentioned occupational health related problem was accidents and injuries at various levels the gold mining process especially during excavation and crushing of the ore.

Table 2: Common Occupational health related problems, 2017

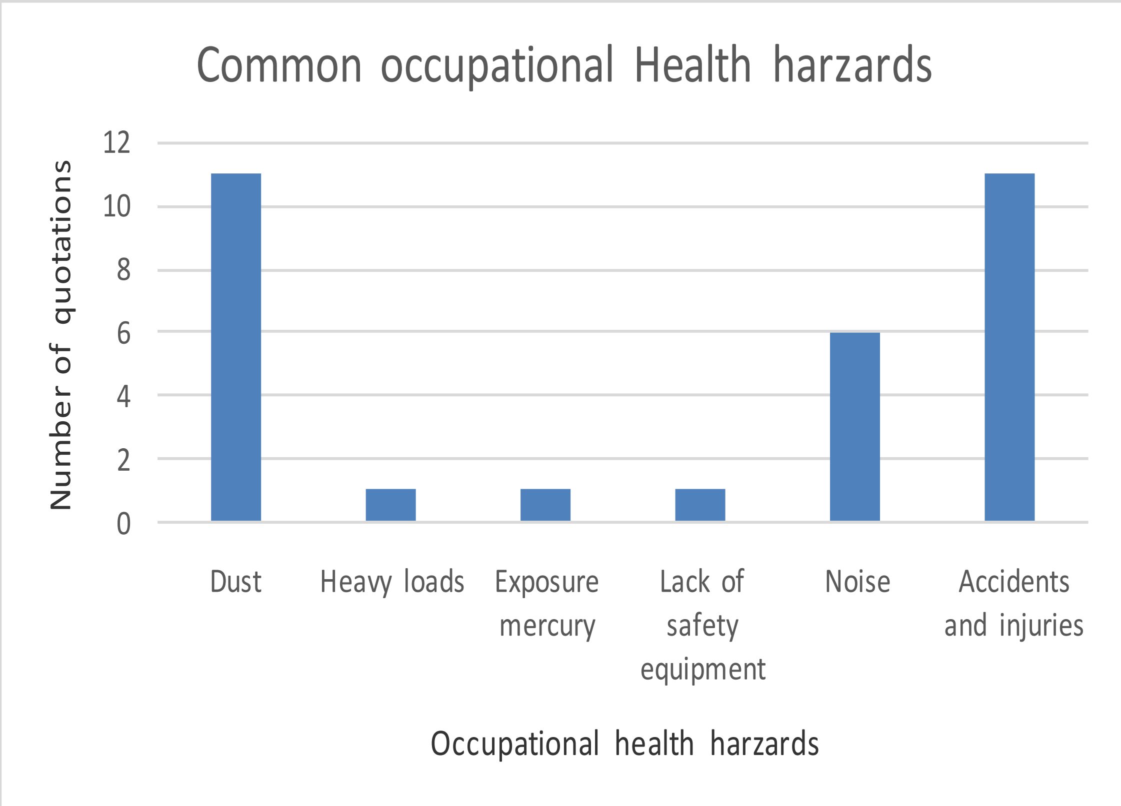


More mercury related effects on the body were reported by women (5 out of 6 quotations) who are mainly involved in the panning process which is one of the stages where mercury is used. Some youth also reported to experience these.

Occupational health hazards and their management

Artisanal small scale miners described various perceived occupational health hazards related to their work including dust, heavy loads. exposure to mercury, lack of safety equipment, noise and accidents and injuries. Exposure to mercury was one of the least mentioned occupational health hazards among the small scale gold miners. This could be attributed to limited knowledge on the harm of mercury.

Table 3: Common Occupational health hazards



Artisanal small scale miners described various methodologies on how they managed these risks. Use of PPE including masks and gumboots was the least mentioned(3 out 23 quotes) way of managing occupational health hazards. Other was mentioned included resting, using mercury carefully, covering pits, self-treatment with pain killers and using more superior tools like heavy duty drills.

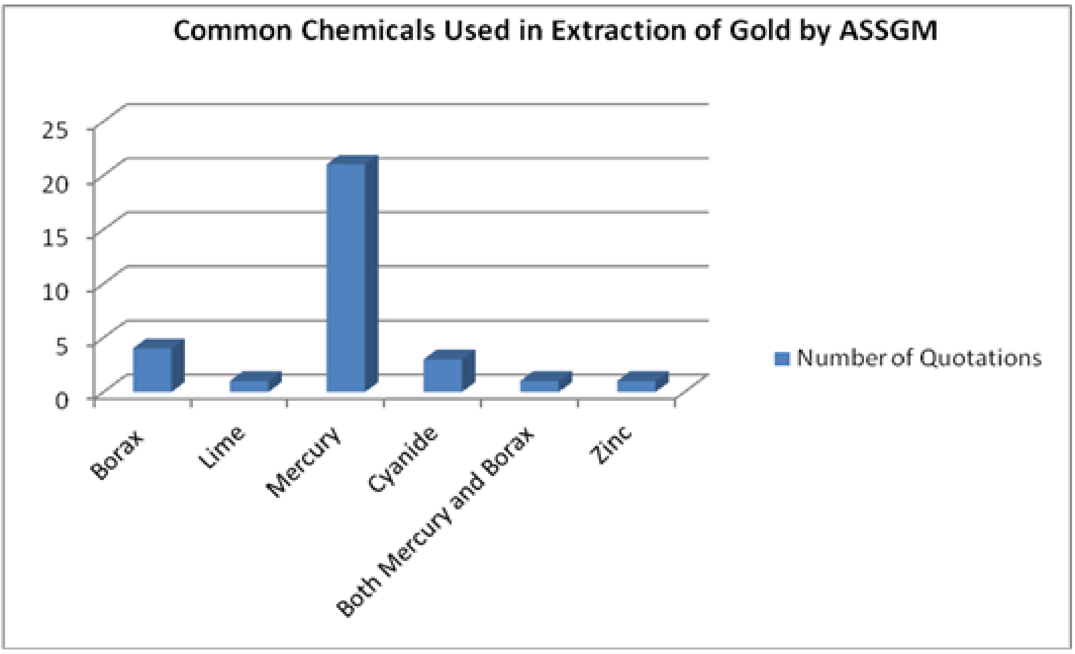
Environment management practices

Respondents indicated there were no environment management practices being implemented miners despite their knowledge on the effects of their effects on the environment.

Use of Mercury and its effects

Mercury was mentioned as the commonest chemical used in gold extraction by Artisanal Small scale gold miners as indicated by 21 quotes on use of mercury out of the 33 quotes on chemical use. A few miners use borax (4 quotes on borax use out of 33quotes on chemical use) and a few of those use both borax and mercury.

Table 4: Common chemicals used by ASSGM in the extraction of gold



Conclusion

Participants indicated various health problems including occupational health related hazards. There were no environment practices being practiced with the use of mercury highly prevalent. Governance structures of artisanal small scale miners were barely existent with some miners organized in small groups. Knowledge on alternative mercury free gold mining methods, knowledge on the use of personal protective gear and improvement in government structures will be key in protecting the environment and health of artisanal small scale gold miners.

3.1.2 Bio – monitoring studies

No human exposure assessments (medical evaluations, bio – monitoring) has been carried out in Uganda; however some ecological assessment studies have been conducted in the past. The following are some examples:

- Using lichens as bio-indicators, Nyangababo (1987; 1) demonstrated the presence of heavy metal pollution in streams feeding into Lake Victoria

- Epidemiological study and biomarkers of exposure, fish contamination data by Ogwok et al, 2009. Results: the concentration of mercury (Hg) in Nile perch belly oil as being within the range of not detected (ND) 5.9 ng/g and 159.90-217.45ng/g for the samples which were analysed.

- Campbell *et al*., (2003; 325) studied the potential accumulation bio-magnification of mercury in the food chain of the fish in Lake Victoria. Campbell *et al.* (2003; 2, 2004; 3) raised concerns about mercury concentrations in Nile Perch.

- The National Burden of food borne diseases study Report:(*FAO/WHO/FERG/UG, 2014): Murchison Bay*
  - At sediment mean depth of 3.5 m and sediment volume of 5.88 m3 the estimated quantity of persistent chemicals in sediment were 0.5 kg of Lead, 2.1 kg of chromium, 0.4 kg of nickel, 0.6 kg of mercury and 0.6 kg of zinc.
  - Presence of Lead and mercury in Nile tilapia fish tissues caught from within the bay which revealed that fish tissues had accumulated in quantities beyond the for mercury).

Table 5: Showing total methyl mercury concentration in tissues of various biotas in Lake Victoria

Species	Date sampled	Location	Length (cm)	Wet wgt (G)	Mean Hg (ng/g dry wgt)
Lates niloticus	08-Feb-95	Nap.G.	23	116	439
Lates niloticus	08-Feb-95	Nap.G.	24	142	409
Lates niloticus	08-Feb-95	Nap.G.	24	142	369
Lates niloticus	08-Feb-95	Nap.G.	29	275	617
Lates niloticus	08-Feb-95	Nap.G.	48	1,400	344
Lates niloticus	08-Feb-95	Nap.G.	55	1,950	536
Lates niloticus (rep1)	08-Feb-95	Nap.G.	71	4,500	605
Lates niloticus (rep 2)	08-Feb-95	Nap.G.	71	4,500	812
Lates niloticus	30-May-95	Nap.G.	39.5	710	495
Lates niloticus	30-May-95	Nap.G.	39	715	345
Lates niloticus	30-May-95	Nap.G.	40	780	394
Lates niloticus	30-May-95	Nap.G.	44	1,000	792
Lates niloticus	30-May-95	Nap.G.	43	955	536
Lates niloticus	19-Oct-95	Nap.G.	47.5	1.250	384
Lates niloticus	19-Oct-95	Nap.G.	53.5	1,900	371
Lates niloticus	19-Oct-95	Nap.G.	39.6	750	314
Lates niloticus	19-Oct-95	Nap.G.	30.5	330	306
Lates niloticus	19-Oct-95	Nap.G.	24	155	370
Lates niloticus	19-Oct-95	Nap.G.	23	135	326
Lates niloticus	19-Oct-95	Nap.G.	17.9	55	359
Lates niloticus	19-Oct-95	Nap.G.	13.8	30	343
Lates niloticus	19-Oct-95	Nap.G.	10.5	9	293
Brycynus sp	19-Oct-95	Bugaia	9	4	81.2
Rastrineobola argentae	19-Oct-95	Bugaia			87.3
Haplochromine sp	19-Oct-95	Bugaia			81
Oreoochromis niloticus	19-Oct-95	Nap.G.	35	1,155	34.6
Oreoochromis niloticus	19-Oct-95	Nap.G.	21.3	200	49.9
Oreoochromis niloticus	19-Oct-95	Nap.G.	15.9	80	110
Caridina nilotica(0)	25-Oct-95	Nap.G.			87.3
Caridina nilotica(5 m)	26-Oct-95	Nap.G.			115

Recommended level: 0.5mg/kg (Codex guideline)

Source: Patricia S. Ramlal1,, Fred W.B. Bugenyi2, George W. Kling1, Jerome O. Nriagu3, John W.M. Rudd4, and Linda M. Campbell5 Mercury Concentrations in Water, Sediment, and Biota from Lake Victoria, East Africa J.* Great Lakes Res. 29 (Supplement 2):283–291
Internet. Assoc. Great Lakes Res., 2003

3.2 Global Studies

Mercury is one of the most researched chemical globally: Examples include:

- Methyl mercury is known to pose substantial heath risks to communities with well characterized fish consumption (Fujuki, 1980, UNEP 2002).
- *Mercury (Hg) Free Gold Mining* **:** Peter W.U. Appel and Leoncio Na-Oy (2012) *The Borax Method of Gold Extraction for Small-Scale Miners. Journal of Health and Pollution: June 2012, Vol. 2, No. 3, pp. 5-10.*
- The United Nations Environment Programme (UNEP) estimated in 2014 that ASGM contributes a 37% share of the man-made emission of mercury to the atmosphere.

4.0 THE OHS&E ASSESSMENT STUDY FOR ASGMs IN UGANDA

4.1 Justification for the Study

4.1.1 Introduction

Artisanal small scale gold mining relates to all the sustainable development goals and will be one of the key sectors contributing to sustainable development in Uganda. The country's vision 2040 also focuses on mineral development as one of the opportunities to be exploited in order to achieve middle income country status. This presented a need to understand the socioeconomic, health and environment impacts and management practices of artisanal small scale gold miners in order to inform future interventions aimed at ensuring sustainable production while protecting the health of artisanal small scale gold miners, and of the environment.

4.2 Problem statements

(1) What is the level of mercury poisoning in gold miners as indicated by clinical and human bio-monitoring assessments?
(2) What are the main sources of exposures, Occupational or environmental (diet, polluted water sources, etc)?
(3) What is the level of ASGM organization and capacity (human, equipment, infrastructure, funds, etc)
(4) What is the level of the miners KAP of OHS&E?
(5) Assessment of the magnitude of related socio – economic impacts.

4.3 Purpose

The purpose of this study was to provide information on the magnitude of OHS&E impacts related to ASGM in Uganda.

4.4 Study objectives

(a) To assess the extent of mercury (and other chemicals) use, environmental contamination/ pollution, exposure and poisoning among ASGMs in Uganda.

(b) To assess the other occupational hazards faced by ASGMs in Uganda.

(c) To determine the existing organisational structures of ASGMs and establish how local and national politics impacts on ASGM.

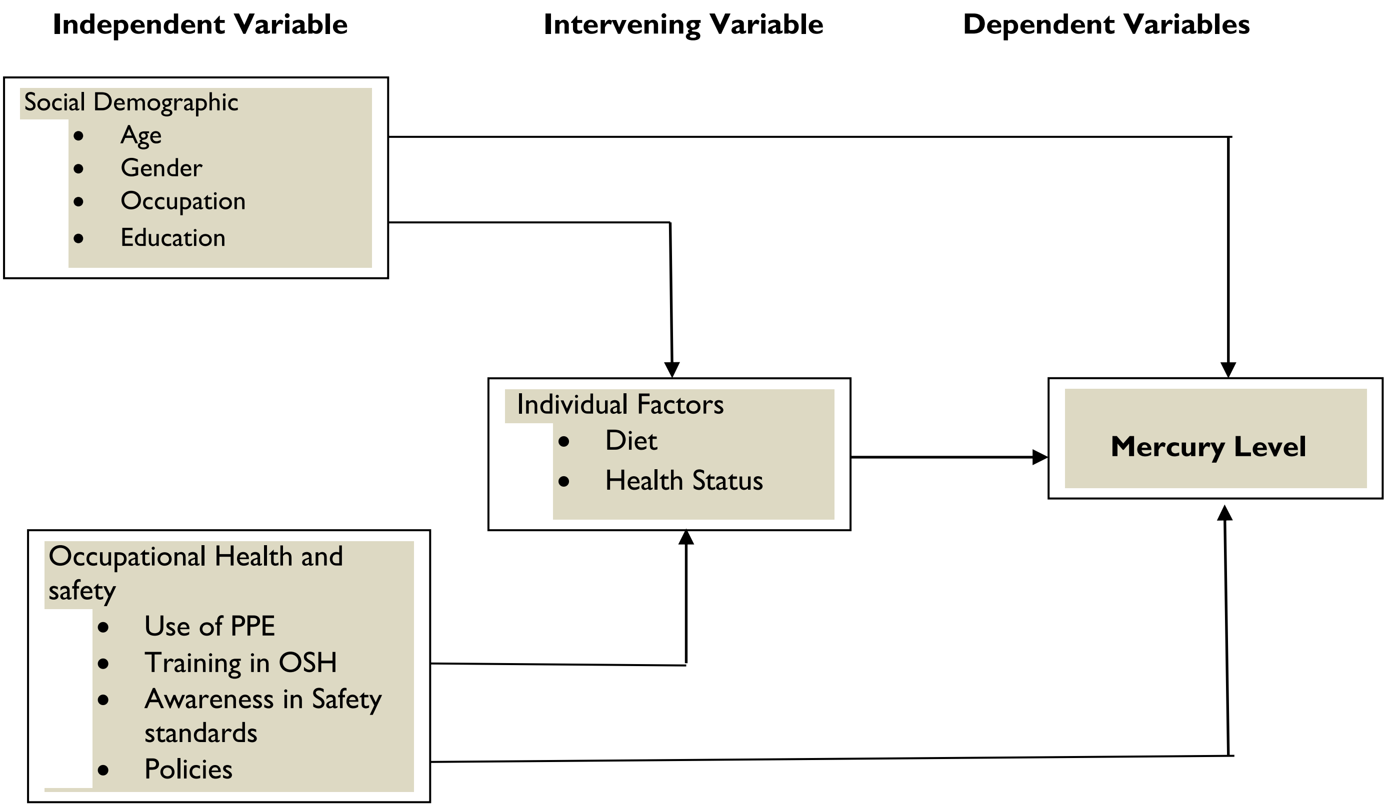
(d) To establish gender, health, safety, enviromental factors affecting ASGMs in Uganda n Uganda

4.5 Research Questions, Hypothesis

(a) What is the magnitude (level) of mercury exposure and poisoning in gold miners in Uganda?

(b) What is the current level of Hg pollution of environmental ecosystems in Uganda?

4.6 Conceptual Framework



5.0 METHODOLOGY

5.1 Study design

(a) Type

This was a cross-sectional study employing both qualitative and quantitative methods. The assessment included key informant interviews, structured interviewer administered interviews, observations as well as conducting human and ecological biomonitoring.

(b) Study participants.

Study participants were selected from the following categories of people.

- Small scale artisanal gold miners at 2 mining sites in the different regions in Uganda.

- Key informants: district officials responsible for livelihoods, health, safety and environment of the communities. These include the District Production Officer, District Health Officer, District Labour Officer, District Community Development Officer and the District Health Inspector, the Chief Administrative Officer (CAO) and the Local Council V (LC5) Chairperson.

(c) Inclusion criteria

- Small scale artisanal miners who had operated in a selected mine for at least 8 months, were present in the mines on day of data collection and who consented to participate in the study.

- A miner who had stayed in the mines for 8 months were selected because he/she were more likely to be exposed to Mercury other than one who had been there for a shorter period.

(d) Exclusion criteria

- Small scale gold miners who had not been actively involved in artisanal small scale gold mining for 8 months, not at the mining site on the day of data collection or those who had not consented to participate in the study or had dental filling with mercury.

5.2 Study area and population

The study was conducted in districts with active ASGMs in the 4 different regions where gold deposits are found in the country (Figure 1).

Eastern region

These include Bugiri, Namayingo and Busia located in the Neoarchean granite–greenstone belt in the S.E of Uganda, which contains the structurally controlled mesozonal Tira gold mine. Some mining sites in this area are located close to the shores of Lake Victoria.

Central region
Mubende district is located in the Paleoproterozoic Rwenzori fold belt. It hosts the structurally controlled metasediment-hosted mesozonal gold mines.

Western region
These include Buhweju, Bushenyi and Ibanda districts which contains structurally controlled intrusion-hosted mesozonal gold mines and the structurally controlled sandstone-hosted mesozonal.

Karamojong Sub- Region
These include Nakapiripiriti, Amudat and Moroto which is located in reworked Archean basement rocks and/or in the upper amphibolite–lower granulite facies rocks of the Neoproterozoic Mozambique fold belt. It also contains numerous hypo zonal shear zone-controlled gold workings.

The study population included artisanal small scale gold miners located in the above mentioned districts. These small scale gold miners often use low technology and machinery in gold mining.

5.3 Sample size calculation

The Kish .L formula was used to determine the sample size. (Ref: Kish L. "Survey Sampling". *New York: John Wiley & Sons, Inc*; 1965: pp164-6)

$$N = \frac{D * Z^{2} * p * q}{d^{2}}$$

Where
$Z_{\alpha/2}$ = 1.96 (standard normal value at α=5% level of significance)
P = Estimated prevalence of mercury intoxication among miners. Based on human bio - monitoring data, from 2010 study among small scale gold miners in Ghana, prevalence of mercury intoxication was 5% (Paruchri et al,2010)
Q=100%-P
d= Maximum error that can be allowed which is 0.05 (Absolute Precision)
D= Design effect

$$= \frac{2 * 1.96^{2} * 0.05 * 0.95}{0.05^{2}}$$

N= 146
Considering a non-response rate of 10%
146 x 1.10

N= 160

5.4 Sampling procedure

Multi-stage sampling was used to select the study sample. All the 4 regions with gold deposits in Uganda were selected to participate in the study in order to make the study representative at national level. Cluster sampling was then used to randomly select one district within each region. Two mining sites were then randomly selected from each of the selected districts. The final sample was drawn from these mining sites using stratified sampling.

The following 3 strata were considered:

(1) Extractors (diggers, ore carriers, driers, stone crushers),
(2) Processors (including panners) and
(3) Burners/ buyers and others.

During the pre-visits, the Mining Site Chairpersons were asked for the list of all ASGMs in the Mining Site, where there was no list, they were requested to make one. All ASGMs in the 8 mining sites were compiled in a statistical dataset with the denominator, and the individual numbers of ASGMs from the 8 mining sites as the numerator. Each mining site was then made a fraction of the total sum of miners. The fraction calculated from the different mining sites were multiplied by **N=160** to get the numbers of ASGMS that participated in the study. This number was determined by the size of the ASGMs at the specific Mining site. From the list of the ASGMs at each mining site, a random sample of a specified number was obtained from a random beginning in each of the strata. Tables 1, 6, 7 & 8 provide summaries of the sampling plans.

Table 6: Sampling plan for respondents

No	Region	District	Study population
1	**Western**	Ibanda	40
2	**Central**	Mubende	40
3	**Eastern**	Busia	40
4	**North Eastern Region.**	Amudat	40
Total	**4**	**4**	**160**

5.5 Human and ecosystem Bio-monitoring Studies

5.5.1 Human Bio-monitoring

Human Bio-monitoring included the following activities:

(a) Health exposure assessment
- Medical evaluations

- Bio – monitoring

(b) Sampling plan and Sampling procedure for biomarker data.

40 participants were randomly selected from the 160 participants and included in the health assessment.

Table 7: Sampling plan for human biomarker assessment

No	Region	District	Blood samples	Urine samples
1	**Western**	Ibanda	10	10
2	**Central**	Mubende	10	10
3	**Eastern**	Busia	10	10
4	**North Eastern Region.**	Amudat	10	10
Total		**80**	**40**	**40**

(d) Sample collection

Human Sample collection, transportation and storage - The DHOs in the study districts designated medically trained and competent officials from one of the health facilities under his/her jurisdiction, who were responsible for medical examinations, collection, storage and transportation of human biological samples (Blood and urine). The purpose was to ensure the selected study districts participated, bought – in and developed a sustainability structure for future studies.

5.5.2 Environmental ecosystems monitoring

Samples from environment ecosystems (water, sediment, soil, plants, and fish) were collected by the environmentalist member of the study team, stored and transported to the Directorate of Government Analytical Laboratory (DGAL) in Wandegeya based on the ecosystem sampling plan below.

All sample collection, packaging, storage, transportation, etc, was based on the WHO/UNEP Protocols for Sample Collection Procedures for Urine and Blood (Annex 9)

- Protocol for Collecting Urine Samples
- Protocol for Collecting Blood Specimens

Table 8: Ecosystem sampling plan

No	Region	District	Water samples	Sediment samples	Fish	Crops (specify)
1	**Western**	Ibanda	4	4	4	4
2	**Central**	Mubende	4	4	4	4
3	**Eastern**	Busia	4	4	4	4
4	**North Eastern Region.**	Amudat	4	4	4	4
Total		**64**	**16**	**16**	**16**	**16**

5.6 Laboratory analysis

Laboratory analysis focused on the presence and levels of Total Mercury, Hg (Mean- Value Mercury level).

The Directorate of Government Analytical laboratories (DGAL), Ministry of Internal Affairs carried out all bio – monitoring sample analysis (human samples, selected food crops, water and sediment analysis and residue analysis).

Testing for heavy metals like Mercury was done using Atomic Absorption Spectrometry. Analysis protocol details are in Annex 6: Methods to determine Mercury in Biological Samples (WHO/UNEP).

5.7 Bio-safety and bio-security measures

Handling of human and ecosystem samples from collection, transportation, storage, analysis and waste disposal complied with national and institutional bio-safety rules and measures including Standard Operating Procedures (SOPs) for medical laboratories, the WHO Occupational health and safety factors(use of personal protective equipment, training in occupational health and safety and awareness of occupational health and safety standards. (EMC/97.3: *Protocol for Safe Transport of Infectious Substances and where necessary, the UN class 6.2 specifications and packaging instructions).*

5.8 Study variables

The main study variables could be categorized as dependent or independent variables depending on the nature of the study. In this study variables were outlined as follows:

(1) Dependent variables

- Mercury levels in human and environmental samples

(2) Independent variables

- Socio-demographic characteristics (age, sex, occupation and economic status)

5.9 Data collection procedures

(a) Instruments (Tools)

- Structured questionnaires were used to collect quantitative data on socio-demographic data, general health problems, occupational health hazards, occupational health problems and gender related issues

- Key informant interviews with open ended questions were used to collect qualitative data on occupational health hazards and perceived health and environment effects of mercury. Key informant interviews will be conducted with the District Production Officer, District Health Officer, District Labour Officer, District Community Development Officer and the District Health Inspector

- Tools used for assessing exposures to mercury were adapted from standardized tools to ensure validity and reliability.

(b) Data collection procedure

Prior to data collection study tools were pretested using respondents from the neighbouring mining sites not included in the study. Additionally research assistants were rigorously trained to ensure validity and reliability of the results. Letters of introduction were provided to the research assistant to introduce them to the leadership in the participating districts and the mining sites. Appointments were scheduled with the study participants where possible. Data collection took about 30 minutes for each interview.

Biological samples and health assessment information were collected by medical personnel recommended by the District Health Officer to enhance participation and involvement from the community**.** Using the listing of participants, one participant was selected from a random beginning in each category of miners until ten participants were selected. The participants were informed about the objectives of the study and importance of collection of human samples of blood and urine. They were reminded that they are free to participate or not to participate in donating the two specimens and informed that they were going to get the results of their samples collected, at the end of the study.

The participant who accepted was directed to the medical personnel who handled the research participant according to the recommended standard procedures. 2 mls of blood was drawn into an already labeled vacutainer and labeled with the participant's National Identity Number (NIN) or a study identifying number. The vacutainers were placed in a cool box. The same participant was given a urine container already labeled with her/his NIN or a study identifying number to collect about 20 mls of urine. The urine sample was again handled according to the recommended WHO standards of handling infectious samples. The urine container was placed in another cool box. As soon as 10 samples of blood and urine were obtained, the cool boxes were handled according to recommended standards and transported to DGAL within a few hours according to the recommended procedures by a qualified Laboratory Technician. Before leaving the field, DGAL was informed to expect the urine and blood samples from the concerned district within a few hours time.

At the end of the study sample results will be given to the PI who will then give them to the DHO and to the participants respectively.

5.10 Tools

Structured questionnaires and observation checklists were used to collect data. Structured questionnaires included:

1) General assessment of ASGM sites questionnaire to obtain information on the basic characteristics of the mining site in relation to gold mining.
2) Individual health assessment questionnaire to capture information on individual's work history in relation to ASGM activities as well as their health history and status
3) Socio-demographics questionnaire to capture information on the socio-demographic characteristics of respondents
4) Health Assessment questionnaire to capture information on clinical symptoms of mercury exposure as well as exposure to mercury of various forms.
5) Food frequency questionnaire to capture information on dietary exposure to mercury
6) 24 hour recall questionnaire to capture information on dietary exposure to mercury
7) Systematic occupational health and safety questionnaire to capture information on occupational

Reliability and validity of study tools

Consultation with occupational health and safety experts was made to ensure validity of the study. In addition use of WHO standardised tools and tests for assessing mercury exposure among artisanal small scale gold miners ensured validity of the instruments. Pre-testing was also done to ensure reliability.

5.11 Pre-testing and training

Training

Three research assistants with prior experience in data collection and knowledge with the local languages of selected study sites and medical personnel were recruited. Data collectors were trained to ensure that they can use the questionnaires, understand the questions, can correctly fill the tools and obtain necessary information from participants. The data collectors undertook a rigorous for 2 days to equip them with sufficient knowledge on the project, the study objectives, tools and research ethic. They were also equipped with data collection skills through role plays and pre-tests. Training covered introduction to the study, objectives, aims, research ethics, assenting and consenting process, and study methodology.

Research Assistants were trained to ensure that they use the questionnaires, understand the questions, correctly fill the tools and obtain necessary information from participants. They were also trained on the data collection tool, research ethics, consent process and how to collect quality data. The semi-structured questionnaires were pre-tested, revised and standardized after the training exercise.

Pre-testing

Questionnaires were pre-tested to ensure that the necessary information is correctly obtained. Based on the pilot results, the instruments were adjusted accordingly and prepared for actual data collection.

During data collection, completed questionnaires were reviewed each day to check for errors in filling, completeness, legibility and other consistency issues. Data was entered immediately after it's collected.

5.12 Data management and analysis

Data management and analysis included or will include the following activities:

(a) Conducting statistical analysis of all the the findings
- Proficiency Testing, Quality assurance and control
- Conducting statistical analysis of all the the findings.

(b) Compilation of the final study report

5.12.1 Data management

The completed questionnaires were cross checked for completeness and consistence. Data was coded, entered using Epi data version 3.1 and imported into Stata version 13 for data cleaning and analysis. Data analysis was done using STATA version 13.0

5.12.2 Data analysis

Qualitative data analysis

The qualitative aspects analysis focused on socio economic status including land ownership, the common causes of morbidity, mortality and health service delivery, environmental management practices, mercury use and governance.

Qualitative data was transcribed and translated. Transcripts were read, discussed and emerging issues used to generate themes. The themes were coded and later analyzed using Atlas.ti7 software

Quantitative data analysis

This involved conducting statistical analysis of all the findings including, among others;
- Proficiency Test, Quality assurance and control

- Conducting statistical analysis of all the the findings.

Table 9: Correlation of blood, hair and dietary intake levels of methylmercury

Geometric mean	25th%	50th%	75th%	90th %	95th %	99th %
Measured mercury concentration in whole blood (μg /L)	1.02	0.4	0.9	2.0	4.9	7.1
Estimated corresponding level in hair (μg/g)	0.2	0.08	0.18	0.4	1.0	1.4
Estimated corresponding dose level (μg/kg day)	0.02	0.008	0.018	0.04	0.1	0.14

Descriptive analysis was used to generate information on the use of mercury, average level of mercury in human samples(urine, blood and hair),average level of mercury in environmental samples(fish, crop and water). Categorical data was summarized using frequencies and percentages. Numerical data was summarized using means and standard deviations for normally distributed data, and median and inter-quartile range for data that is not normally distributed.

Bi-variate analysis was used to establish relationship between the dependent and independent variable. Odds ratios were used to analyze the relationship between the dependent variable and the independent variables. Variables found to be significant at p value of $p \leq 0.2$ were considered for the multivariable analysis.

Multivariable logistic regression was used to determine the factors that are associated with exposure to mercury. Variables found to be statistically significant at $p \leq 0.2$ in bivariate analysis and those considered to have a scientific explanation were entered into the multivariable model and multi-collinearity of variables were tested first.

The multivariable analysis model was built in a backward stepwise method with elimination of variables with $p > 0.05$ in the process to adjust for potential confounders. The findings were reported as odds ratios, confidence interval and independent variables found to have p value ≤ 0.05 at 95% confidence interval were considered statistically significant in the final model

5.13 Ethical Considerations

Emphasis was put on addressing the following ethical considerations:
Ethical review and approval process

- Informed consent
- Confidentiality

(a) General considerations

- Participation in this study was voluntary
- The study was explained to each participant and the participant who accepted to take part in the study signed consent forms for sample collection and storage, prior to enrolment in the study.
- Written Informed consent was sought for respondents above 18years of age and for those below 18 years, assent was sought in addition to consent from their guardians.
- Ethical review, including informed consent of donors and confidentiality was assured
- The District Health Officers (DHOs) were specifically responsible for collecting human biological samples, and provide support for follow – up treatment/management for those respondents(miners) who will be found in need for healthcare attention and consented to be further assisted. During the process patients' rights and confidentiality were or will be observed.

(Consent form for sample collection- Annex 2 &Consent form for sample storage – Annex 3)

(b) Procedures to ensure confidentiality and privacy:

- All persons working on the study were oriented on how to maintain strict privacy and confidentiality.
- To ensure confidentiality, respondents were kept anonymous.
- The blood, urine donors remained anonymous
- The participant's name did not appear anywhere instead an ID No. was used to identify the biological samples and the Personal History Forms, to ensure that it is not be possible to know which responses came from any individual.

Due to the nature and location of the mining sites, it was not possible to set up a tent with screens and an examination couches to ensure privacy during physical examination procedures.

(c) Consent / Assent process:

- The team sought informed consent and assent (below 18years of age) from all study participants.
- In addition, the study participants were assured that the study did not have any negative bearing on their health and that participation is voluntary and would not affect their work or health.
- Parents or guardians provided consent for minors who participated in the study.

(d) Obtain permission from stakeholders *(District Local Governments and Health Facilities):*

- Introduction letters were written to the Health facilities and District Local governments and other key stakeholders.

(e) Benefits:

- Since the questionnaires were very long and participants were kept away from their work for a long time, they were compensated with 10,000 Uganda shillings and a soft drink.

- However, those respondents who were found to require certain forms of healthcare services were not included in the study and were advised to attend the nearest health facilities or higher levels of health care.

(f) Data Management

- Confidentiality in the handling of information and procedures involved in this study was assured through establishing and maintaining a record keeping system, including safe storage of all data at all times.

- Only authorized research personnel were allowed to access the data.

- After the study, all records will be disposed of in a way that ensures that no unauthorized person has access to the confidential information and in line with the national guidelines on management of research archives.

(g) Risks and mitigation:

- Recommendations to conduct the study were obtained from the Ministry of Health and Uganda National Health Research Organization (UNHRO)

- Ethical clearance was sought from the School of Health Sciences Research & Ethics Committee (IRB), Makerere University
- Protection and well-being of study participants were prioritized.

- Extra training of interviewers was conducted based on ethical conduct of research among human subjects including vulnerable populations including minors.

- Respondents were informed before the interview that if they felt uncomfortable answering any question, they were free to skip such questions, or stop participation.

- The national protocol met all national ethical requirements for human subjects including clearance from the Uganda National Council of Science & Technology

5.14 Dissemination of results

- The results will be disseminated in the participating districts as soon as the report is made.
- The results will later be presented to the National Steering Committee of the Mercury Free Gold Mining Project Uganda- New Horizons.

- The recommendations will be discussed for evidence based interventions among ASGMs

Publication plans include;

- Report writing and disseminations (also as for specified requirements e.g to the UNCS&T)
- Publications in national and international journals and websites

6.0 RESULTS

Results of the study were compiled in line with the study objectives as follows:

6.1 Miners' Socio –economic findings

Table 10: Socio – demographic characteristics by region

	Karamoja	Eastern	Western	Central
Gender				
Males	49.02%(25)	74.51%(38)	92.31%(36)	80.00%(32)
Females	50.98%(26)	25.49%(13)	7.69%(3)	20.00%(8)
Marital status				
Married or living	84.00%(42)	79.59%(39)	75.00%(15)	77.50%(31)
together	2.00%(1)	14.29%(7)	15.00%(3)	2.50%(1)
Divorced/Separated	6.00%(3)	2.04%(1)	0	0
Widowed	8.00%(4)	4.08(2)	10.00%(2)	20.00%(8)
Never married				
Education level				
No education	20.00%(10)	12.00%(6)	5.13%(2)	0
Primary	52.00%(26)	38.00%(19)	56.41%(22)	48.72%(19)
O' level	16.00%(8)	32.00%(16)	33.33%(13)	20.51%(8)
A' level	6.00%(3)	8.00%(4)	0	17.95%(7)
Tertiary Level	6.00%(3)	10.00%(5)	5.13(%)	12.82%(5)
Religion				
Catholic	26.53%(13)	31.37%(16)	48.72%(19)	38.46%(15)
Protestant	28.57%(14)	11.76%(6)	46.15%(18)	43.59%(17)
Muslim	14.29%(7)	7.84%(4)	0	7.69%(3)
Pentecostal	24.49%(12)	49.02%(25)	0	7.69%(3)
Seventh Day	6.12%(3)	0	2.56%(1)	0
Adventist	0	0	2.56%(1)	2.56%(1)
Others				
Annual Income				
0-2Million Ugandan	78.43%(40)	80.39%(41)	63.16%(24)	45.24%(19)
shillings	9.80%(5)	17.65%(9)	28.95%(11)	35.71%(15)
2-5 Million Ugandan	5.88%(3)	1.96%(1)	7.89%(3)	14.29%(6)
shillings	5.88%(3)	0	0	4.76%(2)
5-10Million Ugandan		0	0	0
shillings				
More than 10				
Million Ugandan				
shillings				
Age Group				
Less than 18 years	4.08%(2)	0	0	2.44%(1)
18-29 years	42.86%(21)	35.29%(18)	30.77%(12)	56.10%(23)
30-39 years	30.61%(15)	35.29%(18)	25.64%(10)	26.83%(11)
40-49 years	12.4%(6)	19.61%(10)	38.46%(15)	9.76%(4)
50-59 years	10.20%(5)	7.84%(4)	2.56%(1)	4.88%(2)
60-69 years	0	1.96%(1)	2.56%(1)	0

The mean age of the respondents was 33.61years with a range of 15 to 65 years (SD=0.8594592 ,95% Confidence Interval of 31.91633 to 35.31152 years).

Table 11: Living conditions

	Karamoja	Eastern	Western	Central
Occupancy tenure				
Owner/Purchaser	80.39%(41)	74.51%(38)	86.84%(33)	26.19%(11)
Lodger	0	1.96%(1)	0	0
Tenant	19.61%(10)	23.53%(12)	13.16%(5)	73.81%(31)
Type construction materials used for walls and roof				
Walls				
Temporary materials	98.04%(50)	29.41%(15)	45.95%(17)	16.67%(7)
Permanent materials	1.96%(1)	70.59%(36)	54.05%(20)	83.33%(35)
Roof				
Temporary materials	50.98%(26)	13.73%(7)	0	9.52%(4)
Permanent materials	49.02%(25)	86.27%(44)	100%(37)	90.48%(38)

Objective 1: To assess the extent of mercury (and other chemicals) use, environmental contamination/ pollution, exposure and poisoning among ASGMs in Uganda.

Table 12: Use of mercury and other chemicals

Chemicals used at mining site					
Chemical	**Karamoja**	**Eastern**	**Western**	**Central**	**Total**
Mercury	100%(51)	100%(51)	41.18%(14)	73.68%(28)	80.52%(124)
Cyanide	0%	4.55%(2)	0%	28.21%(11)	13.68%(13)
Borax	0%	0%	0%	2.56%(1)	1.05%(1)
Lime	0%	0%	0%	0%	0%
Zinc	0%	0%	0%	0%	0%
Sources of chemicals used					
Source	**Karamoja**	**Eastern**	**Western**	**Central**	**Total**
		Mercury			
Gold buyer	70.59%(24)	16.22%(6)	75%(3)	74.07%(20)	48.78%(40)
Open Market (Chemical traders)	41.67%(10)	88.89%(24)	25%(1)	25.93%(7)	51.22%(42)
		Cyanide			
Gold buyer	-	0	-	10.00%(1)	8.33%(1)
Open Market (Chemical traders)	-	100%(2)	-	70.00%(7)	75.00%(9)
Hospital	-	0	-	20.00%(2)	16.67%(2)
		Borax			
Gold buyer	-	-	-	100%(1)	100%(1)

Other sources of mercury
The Chief Administrative Officer reported that Mercury in this region is bought on the black market from Kenya.

Table 13: Occupational Exposure to mercury

	Karamojong	Eastern	Western	Central
Ever worked with mercury				
Yes No	86.27%(44) 13.73(7)	88.24%(45) 11.76%(6)	36.84%(14) 63.16%(24)	72.50%(29) 27.50%(11)
Average duration of exposure(working directly with mercury)				
Mean ,Standard deviation(SD)	3.59 ,SD± 3.0	9.97 ,SD± 7.60	1.02 ,SD± 0.89	2.45 ,SD± 1.67
Ever worked burning amalgam in open pans or melting gold in inadequate fume hoods				
Yes No	39.58%(19) 60.42%(29)	61.22%(30) 38.78%(19)	25.71%(9) 74.29%(26)	43.59%(17) 56.41%(22)
Mean ,Standard deviation(SD)	3.23 ,SD± 3.0	8.36 ,SD± 7.23	2.06 ,SD± 0.89	2.20 ,SD± 1.48
Ever stored mercury at home				
Never At work At home	43.14%(22) 11.76%(6) 45.10%(23)	18.00%(9) 16.00%(8) 66.00%(33)	70.27%(26) 18.92%(7) 10.81%(4)	53.85%(21) 20.51%(8) 25.64%(10)

Table 13b: Occupational Exposure to mercury

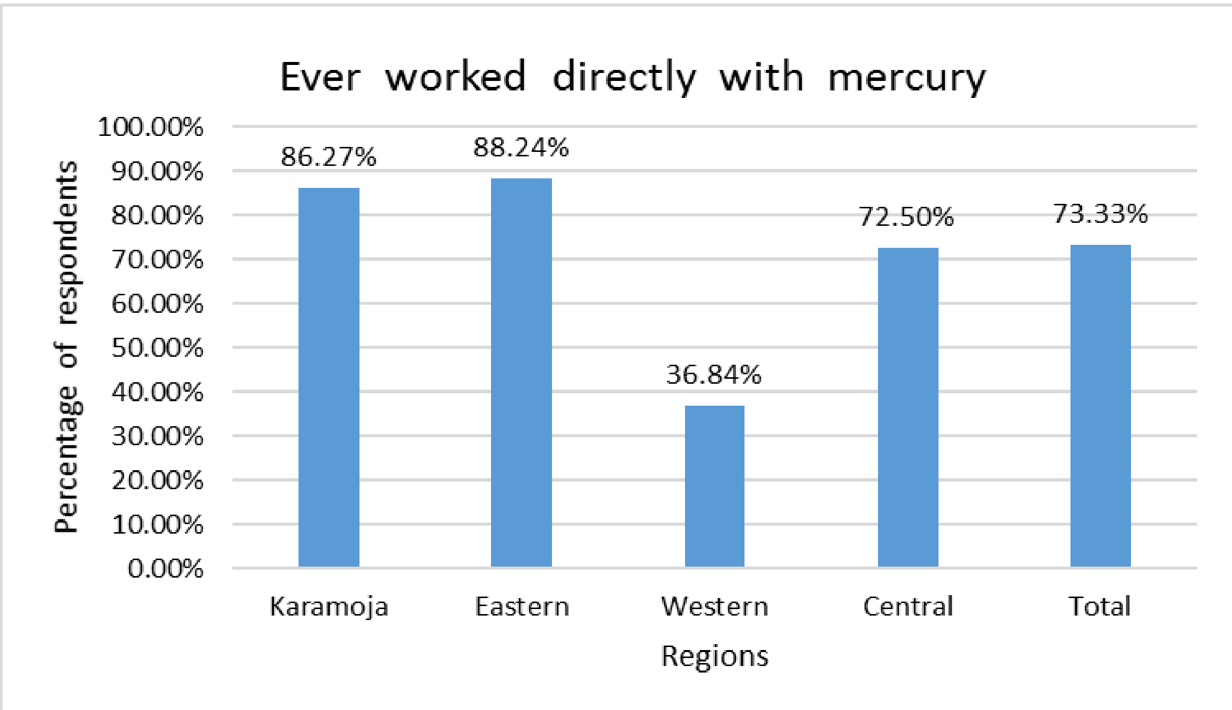


Table 13c: Occupational Exposure to mercury

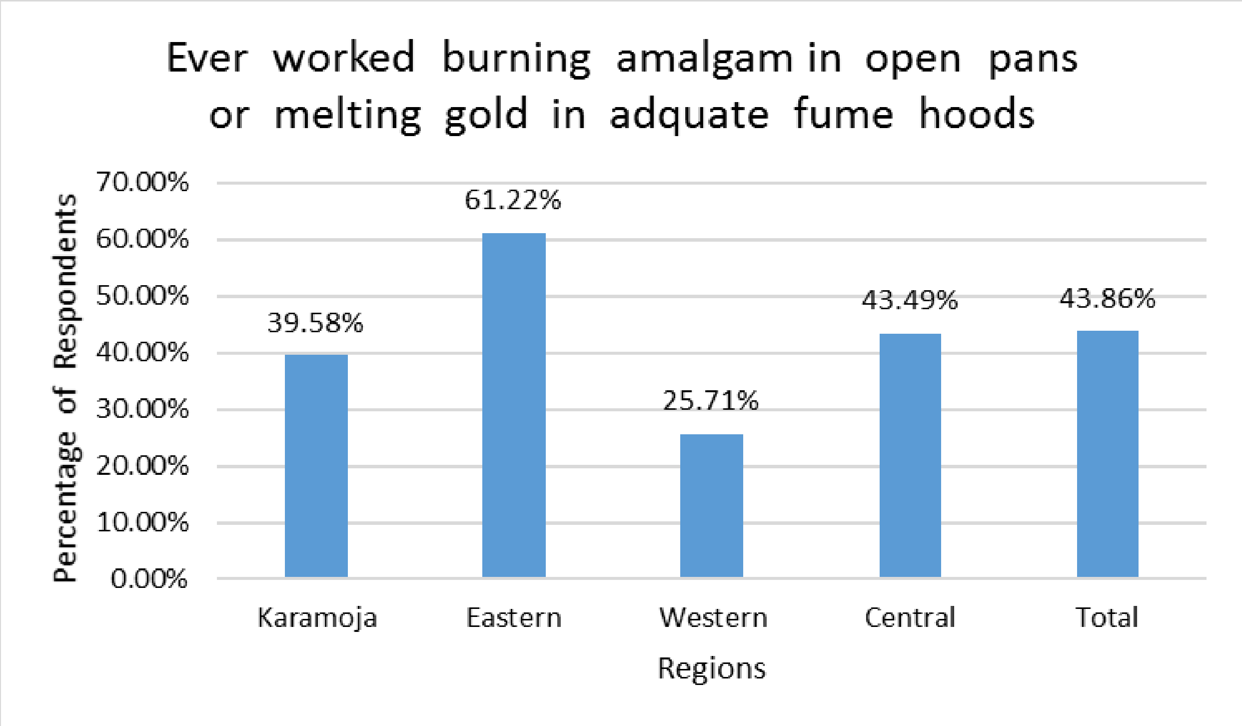


Table 14: Exposure to mercury through diet

Foods		Mean number of times consumed in last 7 days	Common sources	
Red Meat	86.71%(137)	2.30	Market Family livestock Bush	96.27%(129) 5%(4) 1.25%(1)
Chicken/duck	47.41%(64)	1.701	Market Family livestock	66.67%(38) 51.11%(23)
Eggs	63,57%(89)	2.84	Market Family livestock	83.33%(70) 40%(20)
Vegetable	95.18%(158)	5.32	Market Garden	71.92%(105) 57.01%(61)
Fruits	80.85%(114)	4.11	Market Garden Forest/bush	81.31%(87) 45.95%(34) 4.92%(3)
Rice	73.65%(91)	3.87	Market Paddy field Forest	97.00%(97) 30.67%(23) 1.79%(1)
Fish	56.92%(74)	2.58	Market Fishpond River	97.77%(73) 10.91%(6) 4.26%(2)

Table 15: Fish species consumed

Fish species	Frequency
Tilapia	79.59%(78)
Lung fish	21.43%(3)
Mud fish	20.00%(10)
Nile Perch	55.38%(36)
Silver fish	79.12%(72)

Table 16: Health effects associated with exposure to mercury

Symptoms	Odds Ratio (adjusted of known confounding factors)	95% Confidence Interval
Shaking of hands and head*	24.09	1.71 to 338.74
Eye problems*	10.97	1.97 to 62.48
Chest pain*	9.02	3.31 to 24.60
Numbness*	8.51	2.11 to 34.36
Back pain*	6.21	2.20 to 17.50
Fatigue and stress*	5.38	1.94 to 14.88
Headache*	4.67	1.93 to 11.28
Dizziness*	3.84	1.52 to 9.74
Joint pain*	3.23	1.26 to 8.33
Respiratory problems*	3.18	1.01 to 10.12

**Statistically significant association with p value less than 0.05 and 95% Confidence Interval not including zero.*
Adjusted OR obtained from a logistic regression model following adjustment of potential confounders

Photo 1: Miner undergoing clinical assessment, Kakiri, Ibanda

Objective 2: To assess the other occupational hazards faced by ASGMs in Uganda.

Table 17: Observed occupational harzards

Observed occupational harzards	
Biological	None
Physical	Noise, vibration, heat, limited lighting while digging tunnels
Chemical	Mercury,
Toxic agents	Dust, fumes from burning amalgam
Ergonomic	Lifting heavy loads, fatigue, abnormal postures
Psyco-social	Stress, working long hours
Occupational Health practices	
Use of Personal Protective Equipment	
Yes	24.16%(43)
No	75.84%(135)
Awareness of occupational health and safety practices	
Yes	41.34%(74)
No	58.66%(105)

Objective 3: To determine the existing organisational structures of ASGMs and establish how local and national policies impacts on ASGM

Table 18: Existing Miners' Groups or Associations

Region	Group Names
Busia	(1) Siryanyonja Small Artisanal Miners Association (SSAMA). (2) Busia United (3) Tiira Small-scale Miners Association-TISMA
Amudat	Chepkarata Gold Miner's Association
Mubende	Kitumbi- Kayonza Miner's Association

Objective 4: To establish gender, health, safety, enviromntal factors affecting ASGMs in Uganda.

Interviews with Key District Informants

The following officials of the District Leadership were interviewed:

- Resident District Commissioner
- Local Council Five Chairman
- Chief Administrative Officer
- District Health Officer
- District Environment Officer
- District Community Development Officer

Reports by the District Leadership and study participants were as follows:

(1) Accidents

27 out of 70 quotations were received from respondents .The leadership of the participating districts made various observations on the occurrence of mining accidents.

The CAO, Busia reported that a number of deaths had occurred as a result of people falling in the pits, or uncovered open pits. Since the beginning of this year (2018), nine miners had died.

The District Environmental Officer, Amudat reported that the miners themselves dig those holes without taking their safety into consideration. They simply dig deeper and deeper. The district authorities reported cases where such pits collapsed causing death. About 9 people got accidents in 2 pits in 2017.

The Deputy CAO Mubende district reported that the common accidents are of people who are buried into the deep mines. Sometimes they are buried in there so they die.

Photo 2: Rudimental mining. Potential for accidents, Kakiri, Ibanda district

The CAO Ibanda district said that the main problem is accidents within the mines. During the process of mining miners are covered with soil and it happened in Ruchiri sometime back and about 4 or 20 people were covered by soil. Because they dig down the tunnel, when the rocks become weak or water logged they collapse.

Photo 3: Mining pit filled with water, Kakiri Ibanda

(2) Lack of sanitary facilities

11 out of 70 quotations were received from respondents including officials in the study districts. The District Chairman, Busia reported that hygiene in the mining sites is generally poor with people not even using toilets which predispose them to sanitation related diseases. This is largely because in areas where gold is being mined there are no gazetted toilets.

The District Chairman, Ibanda noted that because there are no provisions for toilets, one has to go to the bush. When it rains water will wash away the faeces to the to the river so it is very very dangerous situation to the people

The Deputy CAO, Mubende noted that with regards to sanitation, there are no toilets and people go to the bush. The district has experienced some sanitation related disease outbreaks like cholera most of those mining areas they don't have toilets completely. This scenario was also observed by the Community Development officer, Amudat district.

(3) Exposure to Dust

Information was captured from 4 out of 70 quotations who reported that the mining industry itself has people who have not gone to school, who don't know the implications of their work. The CAO Busia reported that the main cause of dust is the grinding machines that are used to crush rocks into powder. Miners inhale lot of stone dust that adversely affect their lungs.

The District Community Development Officer- Amudat district also noted that these miners are inhaling dust daily. In the long run this will affect their health.

The District Environment Officer Ibanda reported that these gold miners do not wear masks while blasting the stones, therefore they inhale a lot of dust.

(4) Lack of PPE

Information received from 9 out of 70 respondents highlighted lack of PPEs. Miners don't put on helmets, eye goggles, overalls, jackets or the boots. Some of them work while half naked with only a shorts r a pants.
The District Community Development Officer, Amudat said that there is a probability of these people first of all being hit by stones or being buried there. They don't even take those precautions that they are supposed to do.

The District Environment Officer noted that because the miners don't have the protective gear in the work place, they are susceptible to skin diseases from contact with contaminated or polluted water that accumulates in the mines.

4 out of 70 respondents also said that miners are exposed to the mercury because they mine with their bare hand.

(5) Low technology/inappropriate tools

5 out of 70 respondents said that another other challenge is the low technology or no technology used in the mining. Most of the mining is based on unskilled labour. The Deputy CAO Mubende noted that lack of technology makes them achieve little benefit with a lot of strain.

Photo 4: Low technology/inappropriate tools, no PPEs

(6) Noise and Vibration hazards

Noise1 out of 70 quotes was on the noise hazard. The District Mubende Natural Resource Officer noted that mining generates a lot of noise pollution, a lot of dust, and it is a hideous place, contaminated with even human waste.

Vibration received 1 out of 70 quotes. The District Health Officer Mubende reported that miners used to use machines down in the ground which causes vibration but the district did not have data on the its negative health impact the miners and in particular to pregnant mothers.

Photo 5: Miners use electric generators to power drilling machines with no PPEs for Noise or vibration protection. Forest Reserve Kicuzi, Ibanda District

It is important to note that noise and vibrations were not reported on by many respondents may be because they are not considered as health hazardous by the miners.

(7) Environmental effects

Chemical spills were reported by 1 out of 23 quotes. The District Natural Resource Officer Mubende said that spills were managed by basically washing some of these products with cyanide. At one point there was a cyanide spill incident. He noted that mismanaging the spills contaminates wetlands and threatens aquatic life.

(8) Deforestation

Response to the issue of deforestation was from 9 out of 23 quotes. The District Community Development Officer, Mubende noted that due to demand of materials for constructing makeshift shelters for residence and other businesses, miners are cutting down indiscriminately all trees as a result there is substantial deforestation.
The District Production Officer, Amudat also noted that first of all the population has increased due to mining, increasing the demand for fuel in the area. Some of these people have cut trees to produce charcoal. Karita is the worst hit sub county with a lot of deforestation which has affected the environment.

(9) Soil erosion and Environment degradation

In Ibanda district this aspect attracted 6 out of 23 quotes. The Chief Administrative officer, Ibanda noted that miners dig and leave soil everywhere encouraging soil erosion and Water pollution(4 out of 23 quotes)

Photo 6: Soil erosion and Environment degradation, Forest Reserve, Kicuzi, Ibanda District

Photo 7: Miners washing sand in river to recover gold, Kakiri, Ibanda district

The Busia District Chairman, Busia noted that he was told that the miners use mercury to purify the gold and mercury is a metal in liquid form so it contaminates the water sources. These are also sources for watering the animals, for example rivers Namukonde, Okame and Malaba. So when miners wash their gold, they contaminate water sources. For example, when mercury is used in Buena that water will flow through Buteba itself, through Sikuda, through Busitema and it goes to Bugiri as it continues to River Mpologoma so that is a health hazard.

The District Health Inspector Amudat noted that at times when they use chemicals and then when it rains all these chemicals and those other dirt are swept into the nearby water sources.

The District Environment Officer, Ibanda reported that sometimes district Inspectors go there when they get reports from the community with complaints that the water is contaminated.

The Parish Chief, Amudat said that gold mining really affects the environment in such a way that where they have dug now, when it rains heavily like the rains we had of recent there is a lot of soil erosion. They dig holes and do not cover them so it keeps happening again and again.

Photo 8: Degraded ASGM Sites, Forest Reserve, Kicuzi, Ibanda

(10) Destruction of the Ecosystems

2 out of 23 quotes were received. The Busia District Chairman noted that the eco-system is disturbed by the holes the miners keep digging in the ground.

Photo 9: Destruction of the Ecosystems, Kakiri, Ibanda

The District Environment Officer Amudat said that as a result of the deforestation linked to gold mining activities the eco-system is affected.." This was also observed by the District Environment Officer, Amudat.

Photo 10: Destruction of the Ecosystems, Forest *Reserve*, Kicuzi, Ibanda

(11) Social Impacts

(a) School dropout and absenteeism.

13 out of 24 quotes were on School dropout and absenteeism.

The District Community Development Officer, Amudat noted that the district has a school which was constructed by an NGO but the school-going children don't go there because they are involved in mining activities and take much of their time to go for mining with their parents.

Deputy Chief Administrative Officer, Mubende said that there is a lot of school drop outs and absenteeism due to gold mining. For example, compared to other sub-counties in the district in Kitumbi sub-county, the dropout rate is too high. The absenteeism rate is also too high because children believe if they participated in this kind of mining finally they can get out with something.

The District Chairperson, Ibanda noted that both women, men and even children are participating in gold mining and look at gold mining as source of immediate money.

The Chief Administrative Officer, Busia reported that actually mining has removed children from school. The district authorities carried out a fact finding tour of mining areas in Amonikakin and they established that most children go for mining even during school hours.

(b) Child neglect

There were 2 out 24 quotes on Child neglect.

District Environment Officer, Amudat reported that in addition children are not well attended to in terms of meals so they are malnourished because no one cooks for them in time. They eat one meal a day and parents have no time to cook because they are busy in gold mining activities.

(c) Prostitution and HIV/AIDS

9 out of 24 quotes were received related to Prostitution and HIV/AIDS

The Chief Administrative Officer, Busia noted that where there is money is where the prostitutes want to go. A good number of prostitutes are now operating in the gold mining communities. For example, when the district held a World AIDS day celebration in place called Tiira, out of 100 people who were tested, 12 were positive.

The District Environment Officer, Ibanda said that these miners attract women. Women come pretending to be dealing in petty trade like selling bananas, tea in disguise yet they are looking for other things.

6.2 Bio monitoring results

6.2.1 Analytical methods

The blood, urine, soil, Irish potato, yam, sugar cane, cassava, soil, maize, beans, pumpkin, cabbage, solanum leaves, green tomato leaves, fish and water samples were analyzed using a shimadzu atomic absorption spectrophotometer, AAS-6300, mercury Vapor Unit, MVU technique and protocol provided by UNACOH method to determine mercury in biological and other samples (WHO/UNEP) was followed during the analysis of all the submitted samples.

Table 19: Human biomonitoring results

District	Total Mercury (Mean- Value Mercury level)	
	Blood Hg (µg/l)	Urine Hg (µg/l)
Mubende	**136**	**105.5**
Busia	**60**	**70.6**
Ibanda	**43**	**58**
Amudat	**< 0.001**	**< 0.001**

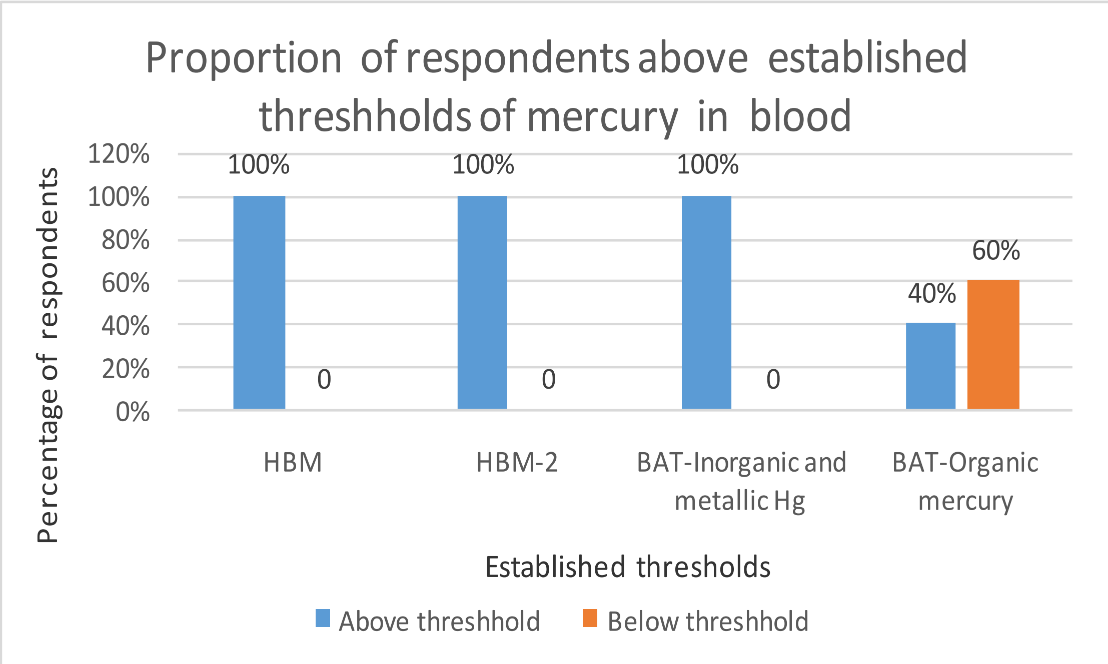
Table 20: Toxicologically established threshold limits for mercury in blood and urine.

Agency	Hg-blood (µg/L)	Hg-urine (µg/L)
Human Bio-Monitoring	5	7
HBM II	15	25
BAT for metallic and inorganic Hg	25	100
BAT for organic Hg	100	
BEI (Biological expo-sure index)	15 (after working)	

Source: UNEP/WHO, 2008

Note:
- *HBM = Human Bio-Monitoring;*
- *BAT = Biologischer Arbeitsstoff-Toleranzwert;*

- *The BAT value is the maximum allowable concentration of a substance or its metabolites in body fluids. It should guarantee that the health of healthy people is not affected when being exposed 8 hours a day or 40 hours a week*
- *BEI = Biological Exposure Indices*



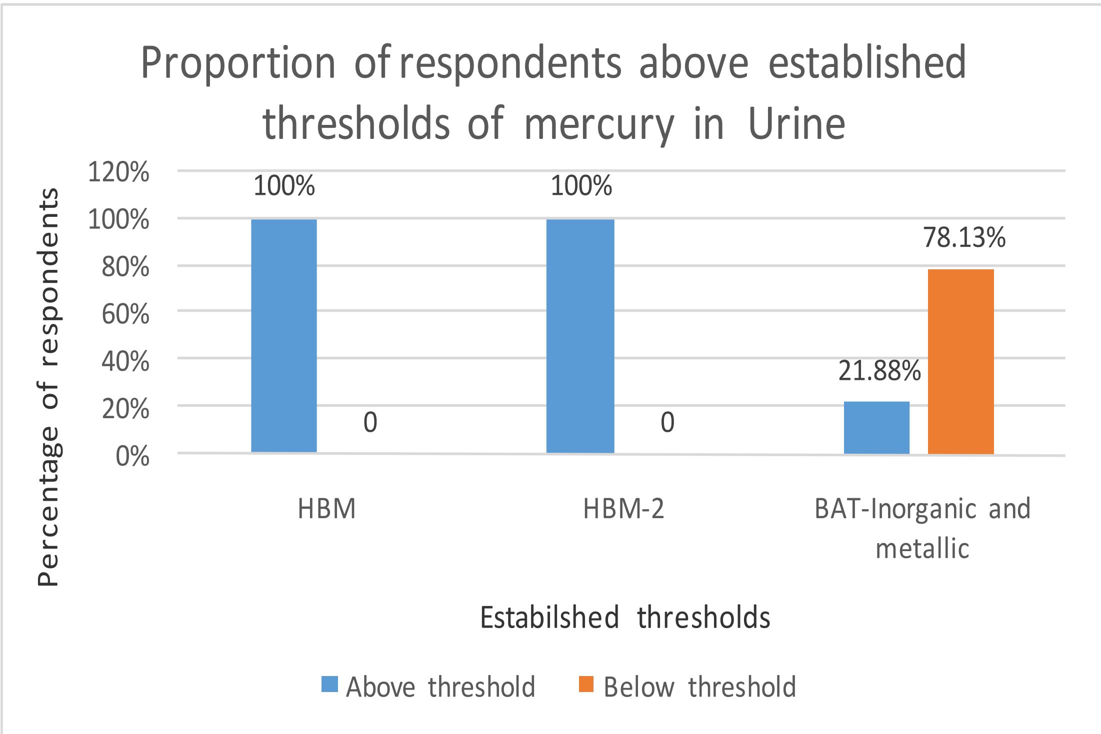


Table 21: Correlation between various characteristics of miners, blood and urine levels.

Characteristic	Median mercury level(µg/l)		Median difference mercury level(µg/l)(CI)		Mann Whitney U test						Kruskal Wallis test					
	Blood	Urine	Blood	Urine	Blood			Urine			Blood			Urine		
					Rank sum	Z(U)	P-value	Rank sum	Z(U)	P-value	χ^2	df	p-value	χ^2	df	p-value
Socio-demographic characteristics																
Gender																
Male	54.4	65.4	-66(- 103.4 to -51.5	69.6(62. 8 to 73)	327	-1.447	0.1479	350.5	-1.981	0.0476*						
Female	104.4	84.7			138			177.5								
Age group																
< 18 years	296	-														
18-29 years	80	75.6									4.927	3	0.1772	4.926	4	0.2950
30-39 years	62.9	53.54														
40-49 years	71.5	141														
50-59 years	63.15	47.05														
60-69 years	-	-														
Education																
No education	65.6	68.6														
Primary	52	62.9									4.541	4	0.3378	2.659	4	0.6164
O' level	61.25	75.4														
A' level	120	53														
Tertiary	128	96.8														
Type of work																
Extractor	52.5	62.9									4.637	2	0.0987	9.595	2	0.0083*
Panner	172.5	109														
Burner	69.4	90.6														
Occupational Health related factors																
Use of PPE																
Yes	119.5	79	-66(- 102.4 to -51)	-66(-72 to - 61.8)	158	454.46	0.1107	133	0.044	0.9653						
No	52.8	69.7			307			395								
Knowledge on OSH																
Yes	119.5	95.6	66 (CI: - 102.4 to -51.1)	-69 (CI: -72 to - 61.8)	177			219								
No	52.25	65.4			288	2.486	0.0129*	309	2.197	0.0280*						

Table 22: Ecosystem biomonitoring

District	Total Mercury (Mean- Value Mercury level)	
	Water Hg (µg/l)	Soil Hg (µg/l)
Busia	31	0.082
Ibanda	13	0.258
Mubende	11	0.256
Amudat	< 0.001	< 0.001

Table 23: Mercury levels in Food

DISTRICT	FOOD SAMPLE	TOTAL MERCURY, HG (Mean- Value Mercury Level)
BUSIA		Hg(ppb)
	Yam	0.288
	Sugar can	0.263
	Cassava	0.133
	Sukuuma wiikie	0.102
	Raw bananas (Matooke)	0.048
	Dried Maize	0.107
IBANDA	Cabbage	0.243
	Yam Leaves	0.261
	Solanum Leaves	0.238
	Green Tomato Leaves	0.287
MUBENDE	Maize point 1	0.256
	Maize point 3	0.218
	Bean point 2 point B	0.218
	Beans point 3	0.266
	Cabbage point 3	0.235
	Pumpkin point 1	0.219
	Sweet potatoes point B	0.245

Note:
<0.001 = Limit of Detection, LOD
1µg/L =1ppb (parts per billion)
1mg/L=1ppm (parts per million)
1µg/L=1÷1000 mg/l= 0.001mg/kg=.001ppm
µg – microgram (10-6 gram);

7.0 DISCUSSION

The study took into consideration the national policy context and was conducted in line with and was intended to contribute to the on – going government initiatives to streamline and harmonize ASGM in the country to ensure that there is harmony between the small – scale miners and the large - scale miners. This also requires amending the Mining Policy and the Mining Act to empower local artisan miners to participate in mining activities.
The study was also intended to support provisions of various national sectoral policies and regulations and provisions of the various Treaties and Conventions where Uganda is Party to and these include the Stockholm Convention on Persistent Organic Pollutants, the Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and their Disposal, the Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the Minamata convention on Mercury (UNEP, 2013) - a global treaty to protect human health and the environment from the adverse effects of mercury and include a ban on new mercury mines, the phasing-out of existing ones, the phase out and phase down of mercury use in a number of products and processes, control measures on emissions to air and on releases to land and water, and the regulation of the informal sector of artisanal and small-scale gold mining, addresses interim storage of mercury and its disposal once it becomes waste, sites contaminated by mercury as well as health issues.
The study also acknowledged that many determinants of health outcomes are outside the health sector, therefore policies and actions in many other sectors have implications for health outcomes. This proposal emphasizes, among others, a multi-sectoral approach and a One Health Approach. To achieve these objectives research is critical for evidence-based policy and decision-making. That is where UNACOH, NAPE and other key stakeholders can play important roles in promoting science –based occupational safety and health and environment management for ASGMs.

Estimating exposure to mercury through biomonitoring include measuring mercury levels in hair, blood, and urine, which are considered forms of "biomonitoring". Measurements of mercury levels in these tissues can be excellent indicators of various types of mercury exposures, but the validity, usefulness, and meaning of such measurements depend on the form of mercury exposures, type of tissue measurement, and other factors. Exposures can be estimated by measuring pollutant levels in various body tissues (such as hair, blood urine, or nails). These measurements of pollutants and/or their metabolites, also known as biological markers (or biomarkers), are useful as tools for human exposure assessment, and 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. The presence of mercury in blood indicates recent or current exposure to mercury (UNEP DTIE & WHO, 2008)..

There is a direct relationship between mercury concentrations in human blood and consumption of fish contaminated with methylmercury. Fish samples can also be considered as a biomarker sample that is worthwhile collecting if information on recent exposure is sought. The presence of mercury in urine generally represents exposure to inorganic and/or elemental mercury, and collection is non-invasive (UNEP DTIE & WHO, 2008).

Urine mercury levels are usually considered the best measure of recent exposures to inorganic mercury or elemental mercury vapour because urinary mercury is thought to indicate most closely the mercury levels present in the kidneys. Hair is generally the preferred choice as it provides a simple, integrative, and non-invasive sample. Once incorporated in the hair, mercury does not return to the blood, thus it provides a good long-term marker of exposure to methylmercury. Most mercury in hair is in the form methylmercury, especially among populations that consume fish. Hair incorporates methylmercury during its formation and shows a relatively direct relationship with blood mercury levels, providing an accurate and reliable method to measure methylmercury intake levels(UNEP DTIE & WHO, 2008). However, hair was no used in this study because of related taboo issues attached to collection of hair in most communities in Uganda.

Once mercury levels are measured in a body compartment (such as blood, hair, or urine), the approximate average daily dose (or exposure level) can be calculated by using various extrapolation or conversion factors. The quantitative relationship between mercury levels in hair and blood and daily average dose (or intake) levels of mercury (especially methylmercury) are fairly well understood. For example, a daily average methylmercury intake of 0.1 microgram per kg body weight per day (0.1 µg /kg per day) by a pregnant woman is estimated to result in hair mercury concentrations of roughly about 1 µg /g, cord blood levels of about 5 to 6 µg /L and blood mercury concentrations of about 4 to 5 µg /L. This relationship is generally linear, or directly proportional.

Biomonitoring or biological monitoring is measurement of the body burden of toxic chemical compounds, elements, or their metabolites, in biological substances. Often, these measurements are done in blood and urine. 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 (IPCS, 2000). 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 (UNEP DTIE & WHO, 2008). The presence of mercury in blood indicates recent or current exposure to mercury. There is a direct relationship between mercury concentrations in human blood and consumption of fish contaminated with methylmercury. The presence of mercury in urine generally represents exposure to inorganic and/or elemental mercury, and collection is non-invasive. Urine mercury levels are usually considered the best measure of recent exposures to inorganic mercury or elemental mercury vapour because urinary mercury is thought to indicate most closely the mercury levels present in the kidneys. Based on the above information, the study team decided to collect blood and urine.

In this study the sample size would have included 68 participants calculated based on a null hypothesis of the mean mercury level is less than 5µg/L, standard deviation of 10.22µ/L (Mensah et al., 2016), power of 0.9 and maximum error of 0.05(two sided). However, due to resource constraints only 120 human samples and 64 eco-samples were collected and analyzed. The sampling plan for human biomarker assessment was based on the UNEP/WHO recommendations.

An ecosystem is comprised of all the non-living elements and living species in a specific local environment. Components of most ecosystems include water, air, sunlight, soil, plants, microorganisms, insects and animals. Ecosystems may be terrestrial – that is, on land – or aquatic. The form of sampling therefore referred to the measuring of biotic and abiotic components of a system in the environment (for example living organisms, such as plants and animals and nonliving things such as air, sunlight, soil and water). Sampling of plants or animals that do not move much, was done using a sampling square called a quadrat which is a plot used in ecology and geography to isolate a standard unit of area for study of the distribution of an item over a large area.

Environmental ecosystems monitoring can be defined as the systematic sampling of air, water, soil, and biota in order to observe and study the environment, as well as to derive knowledge from this process. Air monitoring is done to determine the airborne concentration of the chemical pollutants is usually done to measure occupational exposure through inhalation. Measurement findings are then compared with the set Threshold Limit Value (TLV) and the Short – term exposure Limits (STEL) Standards. This was not done because of resource and logistical constraints. Ecosystem monitoring involves determination of inorganic and organic mercury and other heavy metal residue levels in selected foods, water, sediment and soil samples and comparing with the set Maximum Residue Limits (MRLs).

Bio-safety and bio-security measures are measures aimed at preventing large-scale loss of biological integrity, focusing both on ecology and human health. The methods of prevention include conducting regular reviews of the bio-safety in laboratory settings, as well as strict guidelines to follow. Therefore, Bio-safety is used to protect from harmful incidents. In this protocol the handling of human samples from collection, transportation, storage and disposal complied with national and institutional bio-safety rules and measures including Standard Operating Procedures (SOPs) for medical laboratories. The research team acknowledges that the human and ecosystem sampling is associated with potential biosafety and biosecurity risks. Therefore, the team observed and applied biosafety and biosecurity measures (knowledge, techniques and equipment) to prevent personal, laboratory or environmental exposure to potentially infectious agents or biohazards and ensure the protection, control and accountability measures are strictly implemented to prevent the loss, theft, misuse, diversion, unauthorized access, retention, transfer or intentional release of biological agents and toxins and related resources.

The study assessed associations between mercury levels both in blood and urine and socio-demographic and occupational health related variables. Socio-demographic variables included gender, age group, education level and type of work. The mean age of the respondents was 33.61years with a range of 15 to 65 years (SD=0.8594592 ,95% Confidence Interval of 31.91633 to 35.31152 years). The level of child labour was low, which was attributed the on – going government efforts to enforce compliance to laws prohibiting child labour. Occupational health related variables included among others, use of personal protective equipment and knowledge of occupational health and safety practices.

The district leadership (key informants) in the various ASGM districts made important observations as follows:

(1) Pooling resources to increase capital available to members

The CAO, Busia said that the miners had realized that associations can be used as a bargaining tool and most people who are miners don't have enough capacity to do mining on individual basis. So by making an association is one way of pooling resources which they would use in mining.
The District Coordination and Social Welfare Officer, Busia reported that miners are involved in some kind of loans and VSLA activities. As a group they solicit money so that they can do other things. They also engage in simple IGA like poultry and others just to try and have a sustainable livelihood other than gold mining.
The Natural Resource Officer, Busia said that miners have come together with the purpose of mining, so you can find a group of around 70 people or 20. Others have pooled their resources together and now they employ miners who do the mining for them.

(2) Importance of ASGM Associations as a means for lobbying for funding

The Busia CAO said that associations for gold miners are also used as a bargaining tool, most of them form associations to access funding from government. They had the view of making SACCOS.

The Deputy CAO, Mubende reported that the association was formed with the major focus to see that activities of the gold mines that were banned by government are restored. So it is kind of a lobbying and advocacy association. For them they look at so much of having a single voice to claim to go back to the mines.

However, the key informants identified the following challenges facing ASGMs:

(1) Conflict within groups

The District Community Development Officer, Busia noted that conflicts within mining groups occur frequently. Although at times it doesn't get to authorities, maybe conflict resolutions are managed by themselves. One major thing is that artisanal small gold miners are normally not together in decision making. You find even those in associations don't trust themselves, they don't trust the leadership and level of division is high, yet being together would be okay for them in for example, looking for good gold markets.

Talking to them, you already see the level of division for example when they say "*we could work with you but let so and so not spearhead this. So and so came and helped us and you see originally we were 80 then when this organisation came and put us together, they disorganized us, killed our group and it is only those 10 people who are now moving with them for us we are"*. So the level of unity is too low. As a result miners suffer silently or unknowingly from the negative health effects of this mining. Because the effects are long term, they feeling it and are not willing to work on it and this will affect them eventually with time**.**

(2) Difficulties in obtaining licenses

The Deputy CAO, Mubende noted that the licensing process seems to be so cumbersome for ASGM miners that is why they are more into illegal mining. There are also rumours of people who get money from them in the name of helping them get certificates and licenses. Different officers at different levels come in and each person wants to show them that he is the one who matters just for purposes of extorting money from them.

(3) Bodies supervising the activities of artisanal small scale gold miners

The District Coordination and Social Welfare Officer, Busia reported that recently National Environment Authority (NEMA) was in the district to see the preparedness in terms of environmental impact assessment for a proposed gold mining plant where two or three villages will be affected.

(4) Monitoring by the Ministry of Gender, Labour and Social Development

The District Coordination and Social Welfare Officer, Busia also reported that Ministry of labour comes in especially when it comes to child labour issues.

(5) Challenges in monitoring and supervision

a. Conflicts between local government and ministries

The District Chairman, Busia said that as a district they have tried at times to come in to intervene. But you know what they do when you go there and tell them what you are doing is bad, they run to the ministry and tell them the district is failing us. They say the chairman is failing us so all of a sudden; you will hear the ministry people calling the RDC and telling them please tell the chairman to stop disturbing our investors. I don't know whether the ministry knows what their so called investors are doing there in the district.

b. Monitoring and supervision

Monitoring and supervision is done infrequently and sometimes none at all. The District Chairman, Busia said that he was disappointed that even the government itself which would be the leader in monitoring and supervising and perhaps regulating the activities has done nothing. In fact the people at the ministry are just interested in the money they get that's all. They give miners mining licenses and mining leases for exploration purposes but they don't even follow up to find out what these people are doing down here."

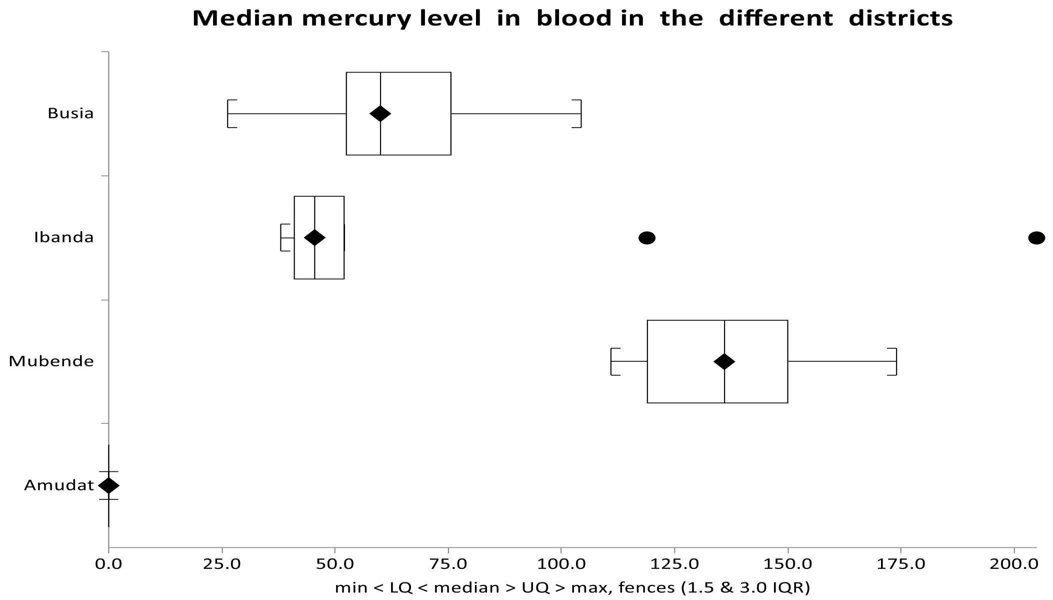
District Environment Officer, Ibanda said that his office has not done much but have a plan to monitor the mining sites. He also said that he has been complaining because the mining procedure of starting with an environmental management impact assessment (EIA) was not followed or ignored and miners continue to extract gold. He lamented that he does not have the capacity to stop them.

The Chief Administrative Officer, Amudat said that in this district there is no monitoring because first of all the district council were against the mining activities in those areas. However, mining is going on in the district t because these mining licenses are dictated by the Ministry (Central government). As a result, there is nobody from the district who monitors them and the people who give them the licenses in Kampala don't come here to monitor the mining activities.

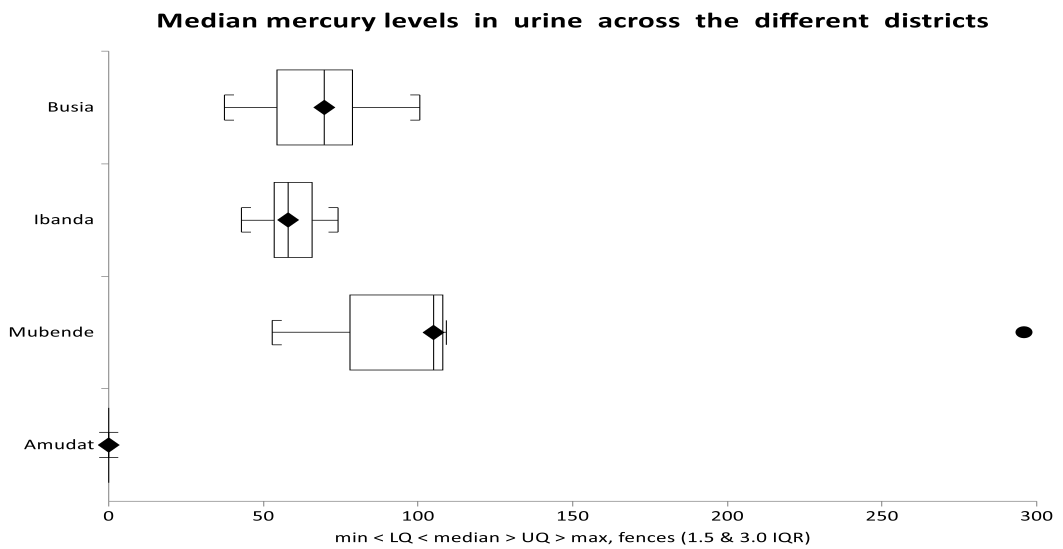
Ecosystem analytical results indicated that in Amudat district there were no levels of mercury detected, LOD=<0.001 in the submitted samples as seen in the table of results above. In Busia district there were no levels of mercury detected, LOD=<0.001 in the submitted samples as seen in the table of results above. In Mubende district some levels of mercury were detected in the submitted samples as seen in the table of results above. In Ibanda district some levels of mercury were detected in the submitted samples as seen in the table of Results, although mercury use is limited. This may be attributed to environmental pollution from other sources.

Bio monitoring results

The median mercury levels in blood and urine samples from different districts indicated a statistically significant difference in median mercury blood levels in the different regions. This was largely attributed to the practice of mercury use, where for example, is a major practice in Busia district.



The Kruskal-Wallis equality-of-populations rank test indicated a statistically significant difference in median mercury blood levels in the different regions(chi square value x^2= 15.147,df=2 and p value =0.0005).



Similarly using the Kruskal Wallis test there was a statistically significant difference in the median mercury urine levels in the different regions(chi square value x^2= 11.664,df=2 and p value =0.0029)

With regard to association between mercury levels and socio-economic and occupational health related variables, statistically significant differences were obtained between mercury levels in urine between males and females with a median difference of -66(95% C1: -103.4 to -51.5) p value of 0.0476 which is less than 0.05. We therefore concluded that there is a difference in mercury levels in urine between males and females. Similarly there was a statistically significant difference between mercury levels in urine between extractors, panners and burners with chi square value of 9.595,df2 and p vale of 0.0083 which is less than 0.05. We therefore concluded that there is a difference in mercury levels in urine between extractors, panners and burners.

Statistically significant differences in both mercury levels in blood and urine were noted among those with knowledge in occupational health practices and those without. The median difference in blood mercury levels for those with and without knowledge in OSH practices was 66(95% CI: 102.4 to 51.5) with a p-value of 0.0129 which is less than 0.05. While the median difference in urine mercury levels for those with and without knowledge in OSH practices was -69(95% CI: -72 to -61.8) with a p-value of 0.0280 which is less than 0.05. This indicates that there are differences in both mercury blood and urine levels between those with knowledge in occupational health practices and those without. Table 25 highlights the correlation between various Miners' characteristics, and blood and urine levels.

Bio monitoring results were also compared with Reference Levels (Standards), namely:

(a) Human biomonitoring results

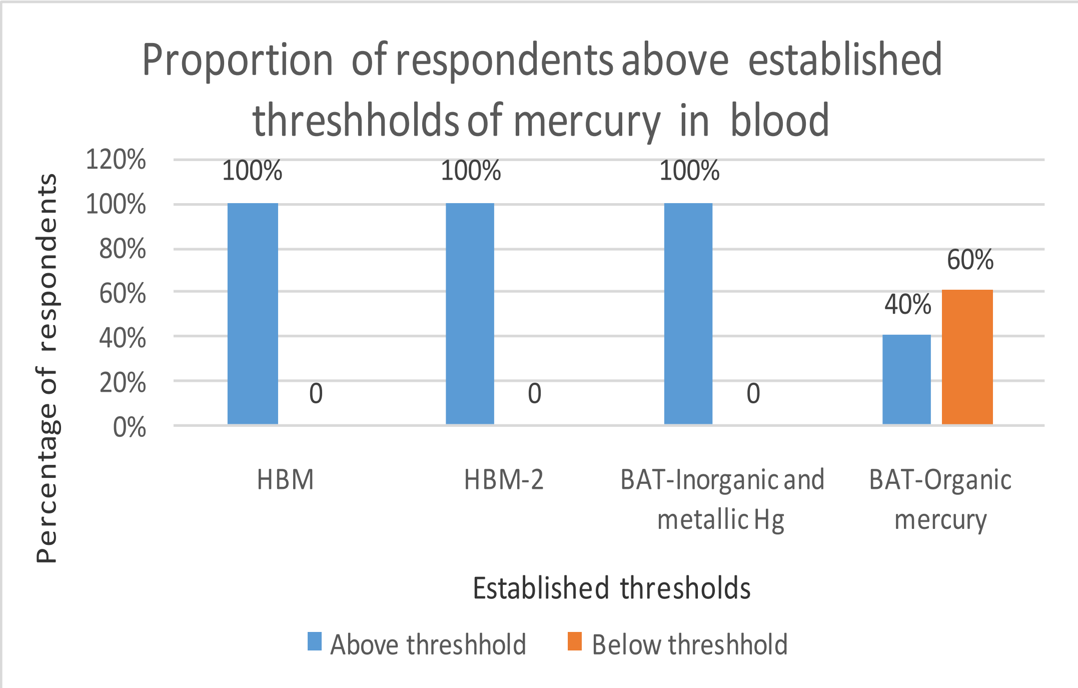
Table 24: Toxicologically established threshold limits for mercury in blood and urine.

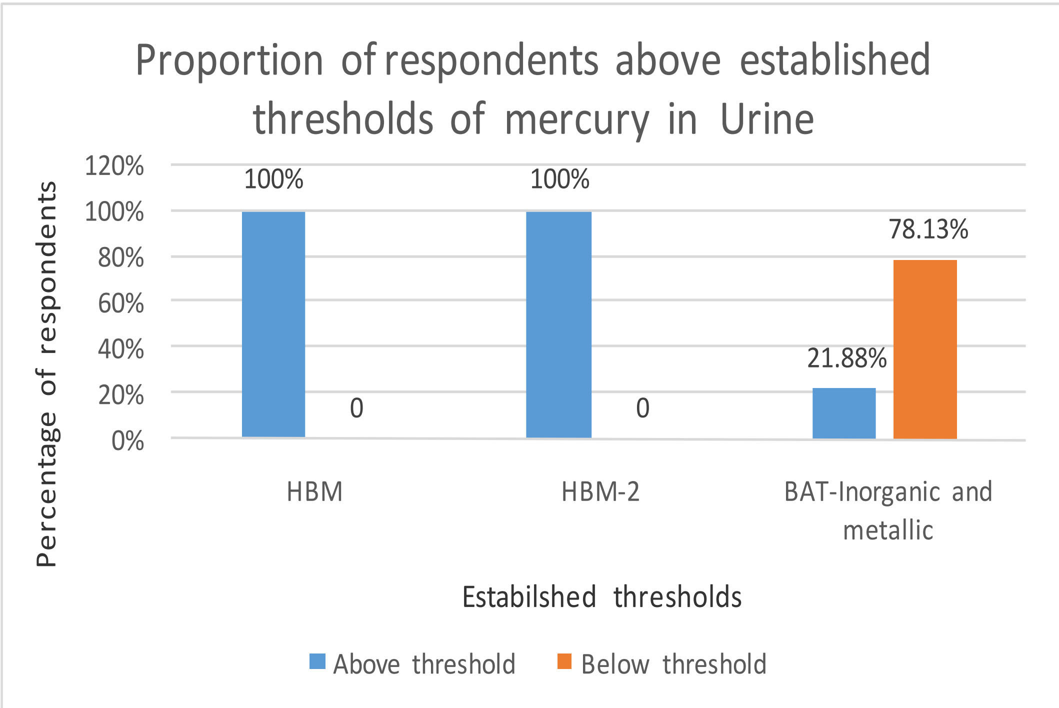
Agency	Hg-blood (µg/L)	Hg-urine (µg/L)
Human Bio-Monitoring	5	7
HBM II	15	25
BAT for metallic and inorganic Hg	25	100
BAT for organic Hg	100	
BEI (Biological expo-sure index)	15 (after working)	

Source: UNEP/WHO, 2008

Note:

- *HBM = Human Bio-Monitoring;*
- *BAT = Biologischer Arbeitsstoff-Toleranzwert;*
- *The BAT value is the maximum allowable concentration of a substance or its metabolites in body fluids. It should guarantee that the health of healthy people is not affected when being exposed 8 hours a day or 40 hours a week*
- *BEI = Biological Exposure Indices*





(b) Ecosystem reference standards

Table 25: National Environmental and Emission Standards for Mercury

Ecosystem	Environmental quality standard (**Reference values)**
Air	Value that sets the guide for reducing health risks from hazardous air pollutant in the environment (guideline value): • Mercury (mercury vapor) no more than 40 ng Hg /m3 (annual average)
Public waterways	• Total mercury content no more than 0.0005 mg/L, and no detection of alkyl mercury (annual average value)
	Effluent standard: • Mercury, alkyl mercury and other mercury compound no more than 0.005 mg/L, and no detection of alkyl mercury compounds.
Groundwater	• Total mercury no more than 0.0005 mg/L, and; • No detection of alkyl mercury (annual average)
	Requirement on ground permeation: • Groundwater cleanup standard-No detection • Mercury, alkyl mercury and other mercury compound no more than 0.0005 mg/L, and; • No detection of alkyl mercury compounds
Soil	• Total mercury no more than 0.0005 mg in 1 litter of sample solution
	Elution standard: • Mercury and its compound no more than 0.0005 mg/L and; • No detection of alkyl mercury Content standard: Mercury and its compounds no more than 15 mg/kg

Source: Ministry of the Environment, Japan; September 2013

Table 26: Judging criteria for regular disposal of treated Special Management Industrial Waste

Waste characteristics	**Concentration of mercury, etc.**
Untreated and treated ash, dust, mining sludge and sludge (excluding waste acid and waste alkali)	Alkyl mercury: not detected Mercury: 0.005 mg/L (in the elution test)
Waste acid, waste alkali, treated waste acid or waste alkali (waste acid or waste alkali), treated ash, dust, mining sludge and sludge (waste acid or waste alkali)	Mercury: 0.05 mg/L (concentration in waste acid or waste alkali)

Source: Ministry of the Environment, Japan; September 2013

(b) Reference levels for daily or weekly methyl mercury or mercury intakes by the FAO/WHO Codex Alimentarius Commission.

- Total methyl mercury concentration Recommended level: 0.5mg/kg (Codex guideline)

- Intake levels for methyl mercury exposures range from 0.7 to 2 μg methyl mercury per kilogram body weight (μg/kg body weight) per week.

- The Joint FAO/WHO Expert Committee on Food Additives (JECFA) - tolerable weekly intakes (PTWIs) for total mercury at 5 μg/kg body weight and for methyl mercury at 1.6 μg/kg body weight.

  (The PTWI is the amount of a substance that can be consumed weekly over an entire lifetime without appreciable risk to health and is an end-point used for food contaminants (such as heavy metals with cumulative properties).

(c) US EPA Reference Doses (RfDs)

- Mercuric chloride of 0.3 μg/kg body weight/day
- Methyl mercury 0.1 μg/kg body weight/day
- A Reference Concentration (RfC) for elemental mercury of 0.3 μg/cubic metre.

(An RfD (or RfC) is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious non-cancer effects during a lifetime).

(d) Fish Maximum Residue Levels (MRLs)

Recommended or legal limits for the maximum allowable amount of mercury and/or methyl mercury in fish to be sold on the market are as follows:

- Codex Alimentarius guideline levels are 0.5 mg methyl mercury/kg in non-predatory fish and 1 mg methyl mercury/kg in predatory fish.

- The European Community allows 0.5 mg mercury/kg in fishery products (with some exceptions), and Japan allows up to 0.4 mg total mercury/kg (or 0.3 mg methyl mercury/kg) in fish.

(e) Converting biomonitoring levels to exposure levels

The mercury levels are measured in a body tissue (such as blood, hair, or urine) can be converted to an approximate average daily dose (or exposure level) by using various conversion factors. For example, a daily average methylmercury intake of 0.1 microgram per kg body weight per day (0.1 μg/kg per day) by an adult woman is estimated to result in hair mercury concentrations of about 1 μg/g, cord blood levels of about 5 to 6 μg/L and blood mercury concentrations of about 4 to 5 μg/L. This relationship is generally directly proportional (*UNEP DTIE & WHO, Geneva, Switzerland, August 2008*).

However, there are limitations, uncertainties and variability in using these conversion factors that should be considered. Exposures to different forms of mercury (such as inorganic mercury from dental amalgams, or methylmercury from fish consumption) will result in different outcomes with regard to tissue levels and clearance. Therefore, exposures to different forms of mercury should be considered (*UNEP DTIE & WHO, Geneva, Switzerland, August 2008)*

Because much of the mercury in fish is methylmercury and most (greater than 95 %) of the methylmercury in fish ingested is readily absorbed into the body through the gastrointestinal tract, individual exposures to methylmercury (or intake) can be estimated if information is available on:

- Types (such as species) and amounts (such as frequency and serving size) of fish ingested per unit time (such as day, week or month);
- Concentration of mercury in the types of fish ingested; and,
- Body weight of person consuming the fish.

With this information, the methylmercury intake for an individual can be calculated by the following basic equation:
Amount of fish ingested per week (g/week) * Mercury concentrations in the fish ingested (μg/g or ppm) = Methylmercury intake per kilogram body weight per week μg methylmercury per kg body weight per week): *UNEP DTIE & WHO, Geneva, Switzerland, August 2008.*

Decision for the diagnosis of possible exceedence of chronic mercury threshold limits for mercury is made based on levels in Table 25. However, fish consumption by these mining communities is not regular and the quantities consumed are small. It was therefore, not possible to make realistic estimates for methylmercury intake from fish consumption.

General observations by the Assessment Team

- The assessment teams were well received by the district leadership and all key stakeholders in the district
- The level of OHS& awareness, risks and requirements by the miners was generally very low
- Most of the respondents were not aware of the use of chemicals , particularly mercury by the ASGMs
- Stakeholders , including miners, were willing and keen to learn about OHS&E issues and how they can be mitigated
- Although accidents and injuries were reported as common, they were largely not documented, un-quantified and in some cases there were deliberate efforts by the miners to hide such incidents from authorities
- There was a deliberate effort by the miners to ensure that children do not get involved in gold mining
- There was urgent need to organize and legalize the ASGM sector, establish and implement OHS&E inspection and monitoring programmes at all levels of governance in the district; and support communities to access and use better mining tools &technologies.

Potential Benefits

The following are some examples of policy and regulatory framework, and structural arrangements that the study team identified, whose implementation could result in improved OHS&E for ASGM activities in Uganda.

- Introduction, implementation and monitoring for compliance of OHS&E measures
- Promote responsible mining in the ASGM industry
- Change/improvement of legal framework and compliance for mining titles.
- Changes/improvement in the process of application for environment and location licenses
- Changes in economic incentives and the current trading in gold towards 'Responsible gold'.
- Change in government and institutional structures agricultural structures.
- Changes in the pollution control measures
- Changes/improvement in relationship between the Large and Artisanal Small-scale Gold Mining groups
- Increased ASM sector activities and advocacy, nationally, regionally and internationally,
- Extension of ASGM training throughout the country
- Strengthened research – based preventive measures in mining activities in the country.
- Building regional and international cooperation and linkages among countries to address issues in ASGM
- Project activities should be mainstreamed not only on project areas but also nationally, by complementing and strengthening activities already undertaken by key stakeholders.
- Change of practices among gold miners will be sustainable if they see an advantage for their health or financial well-being.
- Multiplier effects - These changes in ASGM practices have an effect beyond the mining communities' areas where the project will work and might influence hundreds of thousands of people.

For example, based on similar studies, Japan developed standards for regulations of mercury use in various products as highlighted in Table 30.

Table 27: Regulations of Mercury Use in Products

Product Category	Regulations, etc.
Cosmetics	Ban of the use of mercury and its compounds (Cosmetics standards under the Pharmaceutical Affairs Act)
Agricultural chemicals	Ban of the sale and use of agricultural chemicals that fall under the category of chemical agents containing mercury or its compounds as active ingredient, to be used for the control of agricultural pests (Agricultural Chemicals Control Act and ordinances of the Ministry of Agriculture, Forestry and Fisheries based on the Agricultural Chemicals Control Act)
Sludge fertilizer	Maximum content of allowable hazardous substances in sludge fertilizer (sewage, human waste, and industrial sludge, etc.) -Mercury or its compounds: No more than 0.005mg/L in sample solution -Alkyl mercury: Zero detection in sample solution (Official specifications of regular fertilizers under the Fertilizers Regulation Act)
Product recycled from sludge	Required standards for product recycled from sludge -Total mercury content: No more than 0.0005mg/L in sample solution -Alkyl mercury: Zero detection in sample solution (Standards on the documents and drawings to be attached to the application for the approval of sludge recycling and on the contents of sludge recycling)
Household commodities	No detection of organic mercury compounds in the following household commodities -General household commodities: Household adhesives, household paints, household wax, shoe polish and shoe cream -Textile products: Diapers, diaper covers, bibs, undergarments (undershirts, underpants, leggings, etc.), gloves, socks, sanitary bands, sanitary underpants (Act on Control of Household Products Containing Hazardous Substances)
Pharmaceutical products	Oral preparations: No use of mercury compounds. External preparations: The use of mercury compounds, other than mercurochrome, as active ingredient is not permitted. The use of mercury compounds as preservative is allowed only if there is a special reason that prevents the use of other preservatives for the preparation in terms of safety. (Screening of pharmaceutical products under the Pharmaceutical Affairs Act)

Source: Ministry of the Environment, Japan; September 2013

8.0 CONCLUSION

In the last decade Uganda has experienced an increase of ASGM and use of mercury with adverse OHS&E and other related socio –economic impacts as demonstrated by findings from human and bio -monitoring studies conducted in this study.
In addition, miners and stakeholders are not aware how toxic mercury is, and also not aware of availability of effective mercury-free gold extraction techniques. The ASGM sector is poorly organized, poorly resourced (human, equipment, infrastructure, funds, etc); poorly regulated and poorly monitored. Mining depends on use of rudimental tools and techniques, workers minimal skills in handling chemicals that are harmful to human health and the environment.

These issues compounded by other related negative socio –economic impacts calls for urgent interventions, including operational research to guide these interventions. Other occupational/public health hazards in ASGM include, for example, drug and substance abuse, alcoholism, STIs, child pregnancies and unplanned pregnancies. There are also gender and other vulnerable subpopulation issues in ASGM, for example, child labour, prostitution, unstable families, school dropouts and early marriages. Gold mining and use of mercury also have an influence in local and national politics especially with regard to associated challenges in enforcement for compliance.

There are also related environmental and socio – economic impacts, for example, youth unemployment/employment (job creation, neglect to other socio – economic sector e.g. Agriculture, increase in criminal activities and issues related to mushrooming unplanned peri – urban settlements triggered by the ASGM sites. Stakeholders who participated in the study made the following recommendations:

However the study faced a number of limitations, for example, the study used a smaller sample sizes due to limited resources, which might have compromised generation of statistically significant results. Other constraints included; Source attribution – accounting for other sources of mercury e.g. Beauty creams, soap, hair creams was not possible in this study; Refusal to provide biological samples due to superstition e.g. hair samples were not used; Failure to get appropriate environmental samples for geographical reasons; In most of the study areas there were no lakes or large water bodies therefore few fish samples were collected; Limitations, uncertainties and population variabilities in calculation of the approximate average daily dose (or exposure level) by using various extrapolation or conversion factors, should be kept in mind when doing such conversions; Source attribution: accounting for contributions of methylmercury concentrations in fish from existing background concentrations of mercury, which may consist of mercury from natural sources, as well as historic anthropogenic mercury which has been re-emitted from the oceans or soils. Despite these constraints, the study team is of the view that this was an eye-opener and strongly recommends conducting a similar larger study in the near future.

9.0 RECOMMENDATIONS

The district leadership **(**key informants) noted that the ASGM sector is important for socio – economic development at all levels (household, local communities, district, and national) and made the following recommendations:

Policy & regulatory framework: Government should, as a matter of urgency, organize and legalize the ASGM sector, with priority given to the local communities; fast – track support to the sector, regulate, supervise, and license the ASGMs and eliminate or regulate use of mercury. There is also need to urgently address related environmental degradation; enable the district and ASGMs to get value for money from the gold mining activities; enforce compliance to and ensure environmental protection requirements including Environmental Impact Assessments (EIAs); establish and implement OHS&E inspection and monitoring programmes at all levels of governance in the district.

Institutional arrangements: The ASGMs should form associations to ease their management and support and government should encourage involvement of licensed companies from whom the districts can collect taxes.

Awareness & sensitization of stakeholders: There is an urgent need to strengthen sensitization and awareness on OHS&E hazards, prevention and control measures in ASGM activities; promote use of appropriate PPEs; support communities to access and use better mining tools & technologies.

The mining communities noted that there is an urgent need to organize and legalize the ASGMs sector, with priority given to the local communities and community Associations. They also requested for government support to the local communities since this is their source of livelihood; support mining communities in accessing better gold markets to enable them avoid the risky informal black markets and get value for the intensive extraction labour and the associated occupational hazards, and exploitation by the gold buyers and support mining communities to procure and access affordable tools/machines and technologies including protective gear. Local mining communities should be given priority over the investors. Limit the current priority, support given to investors by government rather than local communities resulting in marginalization and unfair competition. Support miners to implement better financial discipline through saving schemes to limit misuse of the hard – earned money (drinking, prostitution, etc).

The study team recommended that concerned authorities should enforce Environment Impact Assessments (EIAs) as prerequisite for mining licensing; follow –up on environmental protection activities e.g. Audits, monitoring for compliance to environmental protection requirements. The mining districts should establish focal persons at various ASGMs and networks to enable them monitor the sub-sector, coordinated through the LC system; strengthen efforts to sensitize the miners on ASGMs related OHS&E hazards; close the mines in some areas which are at highest risk; enforce phasing out the use of mercury and promote use of alternative chemicals and technologies.

10.0 ANNEXES

Annex 1: Key informant responses, Ibanda District

QUESTIONNAIRE	DISTRICT LEADERSHIP RESPONDENTS: IBANDA DISTRICT						
	RDC	LCV Chairman	CAO	DHO	DEO	DCDO	Local Communities
Section A: Socio-economic status							
1) What are the main sources of live hood in this gold mining community?	Mainly Agriculture (Coffee, Bananas, horticulture, animal husbandry, trade)	Mainly Agriculture (Coffee, Bananas, horticulture, animal husbandry, petty trade) A smaller section of the community are engaged in gold	Agriculture, timber cutting, petty trade	Agriculture(bananas, coffee, etc) Gold mining is a supplementary activity	Agriculture Gold mining but economic benefits are largely unknown and not quantified because this is largely an illegal activity	Mainly agriculture Casual labourers Petty traders	Mainly agriculture But gold mining provide better financial gains

		mining					
2) In the areas where gold mining occurs, who owns the land where mining sites are located? How do the artisanal small-scale gold miners acquire the areas in which they mine gold?		Individual land Hired land Most miners are not licensed	Individual land Hired land Encroachment on public/government land (game & forest reserves)	Individual land Government land (e.g. forest reserves) Hired/Rented land from local land owners Government leases to Investors	Individual land Hired land	Individual land Hired land Encroachment on public/government land (game & forest reserves) especially in Kicuzi	Individual land Hired land
3) In your opinion, do you think social services (including health care, education, transport services, electricity) are accessible, available and affordable for artisanal small-scale gold miners?		Services are provided by government in general and in some cases by the private sector Not specific for gold miners Readily available and accessible	Limited accessibility since ASGMs are illegal activities mostly in protected areas	Limited especially in the mining areas HC3s are available and accessible Private health service providers	Services are available like in other places in the district but not particularly targeting the ASGM sites Some services are limited because ASGMs are generally not easily accessible	Reasonably available in the county but not in the mining sites None in the reserve land areas HCs available but not readily accessible for some communities	

		but sometimes not affordable especially those provided by the private sector					
Section B: Health and safety.							
1) What are the common health problems people faced by in this gold mining community?		Poor or non –existent sanitation facilities Pollution of water sources with soil or chemicals Skin diseases due to poor personal hygiene	River Blindness (Oncocerciasis), Malaria, Marburg disease, Physical injuries and accidents, No PPEs (wear & equipment) Insecurity ASGM Illegal activity	Malaria is commonest due to mosquito breeding in open pits High prevalence of epilepsy whose cause is not yet established (may be associated to Oncocerciasis which is also prevalent in the area) Alcoholism and other anti –social behaviours	Malaria Skin diseases Respiratory illnesses e.g. TB Marburg (Bats in old mines) HIV/AIDS Prostitution	Accidents and deaths due to Soil/mine collapses Unsanitary conditions Marburg outbreak in Kitaka mine	Some said that they had heard that mercury causes male impotence

2) Where do artisanal small-scale gold miners commonly seek health care? In your opinion are health care services affordable, accessible and satisfactory? Please explain?		From public health facilities (HC2, HC3),fairly accessible and satisfactory, including a referral system to higher hospital systems From private health facilities, rather expensive	In Kicuzi there is Kanywambogo Health Centre 3 (HC3) ,but not easily accessed	Health Centres (HC2, HC3) Private clinics Referrals to larger district hospitals	Health centres are reasonably available, easily accessed and provide satisfactory services.	Health Centres (HC2, HC3). The nearest is about 5Km away Private clinics Drug shops	
3) What are the common safety hazards experienced by artisanal small-scale gold miners and how are they managed?		Many mining accidents and injuries Six people were buried and died from collapsed mining pits, In 2017	Physical injuries and accidents, including deaths. No PPEs (wear & equipment Increase in disease outbreaks	Physical injuries and accidents, including deaths. No PPEs (wear & equipment Use of rudimental tools Increase in disease outbreaks	Accidents and injuries No PPEs Poor sanitation Unsafe water supply	Accidents, injuries, deaths No PPEs Poor sanitation, no latrines Unsafe water supply However some areas have access to	

				Low latrine coverage		piped gravity water and protected springs	
Section C: Environment Management Practices.							
1) In your opinion, have the activities of artisanal small-scale gold had any effects of on the environment? If yes what are effects and how do they affect the environment.		Environmental degradation is the major concern Most pits are left un – filled , not restored (open pits) that are risk to accidents or breeding grounds for mosquitoes Pollution of water sources	Yes. Soil erosion Environment degradation Pollution of water sources	Environmental degradation Pollution of water sources and other ecosystems Poor sanitation and poor latrine coverage Abandoning agricultural activities resulting into food insecurity	Malaria - Open pits (stagnant water, mosquito breeding areas) Landscape degradation Deforestation and vegetation destruction Pollution of water sources and other ecosystems	Soil/land degradation vegetation and landscape destruction Pollution of water sources (Swamps, wetlands, R. Mpanga, L.George)	

2) Do you know of any environment management practices carried out by artisanal small-scale miners to protect the environment?		None, Miners are not even bothered District management feels that these activities should get organized or be stopped	The District is encouraging tree planting and has provided seedlings to affected communities	None by the ASGMs Some communities are accessing Gravity water Schemes developed by the district and with donor support	Some effort in tree planting and afforestation , privately driven and by NGOs/CBOs	None	
Section D: Mercury use							
1) What are the common chemicals/materials used to extract gold and what are the common sources of these chemicals and how much do they cost?		Not aware that chemicals are used in Kakiri, only physically wash the soil/sand to recover the gold In Kicuzi mercury is used to extract the gold	Mercury to extract gold	Initially only water was used and no chemicals, Use of mercury was introduced later	Only heard about use of mercury but not seen it personally	Not aware of use of mercury or other chemicals Extraction of gold (washing of gold - containing soil/sand) is done using river water not chemicals	
2) How are these chemicals used? Describe the		mercury is manually added	Not sure	Not sure	Not sure	Not sure	

process?		to crashed stones or soil to extract the gold					
3) In your opinion, are these chemicals dangerous to the environment? If yes, how?		Yes, because they are discharged or dumped without proper disposal methods		Yes. Directly poisoning people or indirectly through the food chain	Yes		
Section E: Governance.							
1) Are miners organised in associations in this community? If yes, can you mention any groups you know of? What kind of work do the group do?		No	Mining groups not organized	Not organized No ASGM associations The bigger mining companies are more organized	Mostly an illegal activity Not organized No associations	Activities are largely informal Attempts have been made by the District Environment Office to organize the ASGMs (2018) Some organized groups have been formed.	

2) Do you know of any bodies monitoring and supervising the activities of artisanal small-scale miners in this area? What do they do and how often?	The RDC has personally visited these areas and sensitized the miners and got them to work in a more organized manner The RDCs Office has established focal persons at various ASGMs and networks to enable him monitor the sub-sector, coordinated through the LC system	No because these are illegal activities	The District Natural Resources Department Conducts sensitization and awareness programmes	None at the district level Companies and individuals claim that they are only prospecting not mining gold, therefore there is no justification for district controls	Miners who are licensed conduct some supervision and monitoring activities which are commercially driven	The Sub- county Council The District Natural Resources Department Efforts have been made to sensitize the miners on ASGMs related hazards and also to close the mines in some areas which are at highest risk	
3) What the common challenges faced by artisanal small-scale gold miners in this community?		There is minimal value for money by the locals considering that the gold quantities are usually small, extraction is labour intensive	Limited access to social services Insecurity	No major public health issues yet No PPEs Use of rudimental	Use of rudimental tools and methods Insecurity Anti – social	Accidents Use of rudimental tools and methods No PPEs	Not aware of the dangers of mercury use No access to affordable tools/machines

		and selling is conducted informally at black markets. Dealers at the higher level of the chain benefit most.		tools and methods Insecurity	behaviours(e.g. fighting, alcohol and substance abuse)	Exploitation of miners by the gold buyers Labour intensive and hazardous activity Poor economic returns for some stakeholders	and technologies No access, affordability or availability to protective gear Priority, support given to investors by government rather than local communities resulting in marginalization and unfair competition Misuse of the hard – earned money (drinking , prostitution, etc)
Recommended Actions							
	This sector is	Government	Legalize the gold	Eliminate or	Organize and	Organize and	Request for

	important for socio – economic development at all levels(household, local communities, distrct, national) Government should fast – track support to the sector regulate, supervise, organize and license the ASGMs	should support the sector supervise, organize and license the ASGMs The ASGMs should form associations to ease their management and support There is need to urgently address related environmental degradation	mining activities Get the ASGMs organized Encourage involvement of licensed companies from whom the district can collect taxes Enable the district and ASGMs to get value for money from the gold mining activities	regulate use of mercury Promote use of PPEs Strengthen sensitization and awareness on OHS&E hazards, prevention and control measures in ASGM activities	legalize the sector License the business enterprises Enforce Environmental Impact Assessments (EIAs) Enforce compliance to and ensure environmental protection requirements	legalize the sector Scale – up OHS&E sensitization and awareness activities	Government support to the local communities since this is their source of livelihood Organize and legalize the sector with priority given to the local communities

General observations by the Assessment Team

1. The assessment teams were well received by the district leadership and all key stakeholders in the district
2. The level of OHS& awareness, risks and requirements by the miners was generally very low

3. Most of the respondents were not aware of the use of chemicals , particularly mercury by the ASGMs
4. Stakeholders , including miners, were willing and keen to learn about OHS&E issues and how they can be mitigated
5. Although accidents and injuries were reported as common, they were largely not documented, un-quantified and in some cases there were deliberate efforts by the miners to hide such incidents from authorities
6. There was a deliberate effort by the miners to ensure that children do not get involved in gold mining
7. There was urgent need to organize and legalize the ASGM sector, establish and implement OHS&E inspection and monitoring programmes at all levels of governance in the district; and support communities to access and use better mining tools &technologies.

Note: Acronyms for Key Informants

RDC	-	*Resident District Commissioner*
LCV	-	*Local Council Five Chairman*
CAO	–	*Chief Administrative Officer*
DHO	–	*District Health Officer*
DEO	–	*District Environment Officer*
DCDO	–	*District Community Development Officer*

Annex 2: Assessment Tools

(1) General Assessment of the ASGM Sites
(2) Individual Health Assessment - History and health related Questionnaire.
(3) Informed Consent Form
(4) Certificate of Consent for Sample Storage
(5) Methods to Determine Mercury in Biological Samples
(6) Socio-Economic - Demographic Questionnaire (Key informant interview guide)
(7) Health Assessment Questionnaire
(8) Sample Collection Procedures for Urine, Blood, and Hair
(9) Food Frequency Questionnaire
(10) A 24-Hour Recall Questionnaire
(11) Systematic Occupational Data Collection Sheet
(12) Step By Step Risk Communication Guide for Mercury in Fish

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