

The Health and Ecological Implications of Mercury use in Artisanal Gold Extraction Process

IJOTM
ISSN 2518-8623
DOI: 10.67610/ijotm.3.1.003
Volume 3. Issue I
p. 12, June 2018
http://jotm.utamu.ac.ug
email: ijotm@utamu.ac.ug

Herbert Nabaasa
hnabaasa40@gmail.com
Mbarara University of Science and Technology

Willy Ngaka
Centre for Life Long Learning
Makerere University Kampala, Uganda

Epiphany O. Picho
Muni University

Abstract

This paper presents findings of the study to examine the implications of Mercury use in artisanal gold mining on the ecological systems and the miners' health. Mercury is extensively used in gold extraction by artisans with implications on their health and the environment.

Although Artisanal Gold Mining is an important economic activity that underpins the livelihoods of many people in Uganda and elsewhere in worldwide, the public health and ecological issues particularly, the mercury use in the gold extraction process are of great concern. Unfortunately, the major focus in Sub-Saharan Africa has traditionally been on large-scale mining with less interest on health, safety and environment issues in artisanal gold mining (Collier, 2010).

An exploratory cross sectional study design was used to examine the implications of Mercury use in artisanal gold mining on the ecological systems and the miners' health in the districts of Mubende and Buhweju. 384 respondents were selected from artisans, minining rights holders and local leaders. Data was collected using observation checklists, survey questionnaire, interview guide and documents review guide.

The findings indicated a strong correlation between the variables of interest determined using odds ration and 95% confidence intervals. It was established that, the mining communities live in deplorable sanitary conditions, use toxic chemicals such as mercury in the gold extraction process putting their health at a great risk and have severely degraded fragile ecosystems that should support their livelihoods.

In order to assess the relationship between the use mercury in gold extraction and ecological/health implications, all the factors that were significant at bi-variate level were subjected to a multivariate analysis using logistic regression model. The significant factors such as the implication of mercury use on land and water, miners' livelihood security and food production were fitted in the model and subjected to further analysis.

A Back Ward Stepwise Logistic Regression was used to control for all probable confounding variables in the test. The controls were done through model modification. The best logistic regression model fitted finally predicted the probability or chance that mercury use in gold extraction significantly affects the miner's health and ecological value.

Key words: *Mercury use, Artisanal Gold Mining, miners' health and ecological value*

Introduction

Artisanal mining refers to the exploitation of marginal or small deposits of minerals by individuals, groups or organizations with minimal or no mechanization. Artisanal gold mining is an important economic activity that underpins the livelihoods of many people worldwide despite the little attention regarding its regulation, formalisation and public health discourse. In Sub-Saharan Africa, the focus has traditionally been on large-scale mining of oil, gas and mineral resources that have tended to benefit the elite, often adding very little value to the sustainable growth of economies (Collier, 2010).

In Uganda, Artisanal and Small Scale Gold Mining is on the increase and is largely a poverty-driven activity used as a coping mechanism (MEMD, 2011). Thousands of communities in Uganda are currently involved in "gold rushes" with a hope to improve their way of living. However, most artisanal gold mining practices take place in highly fragile ecosystems and agricultural fields with implications on people's livelihoods (Hinton, 2011). The miners' health and ecological issues associated with artisanal gold mining are of great concern particularly, the use chemicals such as mercury which presents public health risks not only to the miners but also to the entire community that lives near the mining sites.

The use of mercury increases the risks associated with environmental degradation, occupational safety and community health and wellbeing. The risks from mercury use are both direct and indirect. The direct effects are from the day to day interaction with mercury during the gold extraction processes while the indirect risks are from the consumption of mercury polluted water and food along the food chain.

Despite the growing interest in artisanal gold mining as a livelihood enterprise, the practice presents major health and environmental risks. The study was thus intended to examine the health and ecological implications of Mercury use in Artisanal Gold extraction process with a view to make recommendations for safe and sustainable exploitation of artisanal gold.

Specifically, the study was aimed at; exploring the practice of chemical use in artisanal gold mining in Uganda and examining the critical implications of using such chemicals in the gold extraction process on the miners' health and the ecological value.

Thus, an exploratory cross sectional study design was used to examine the implications of Mercury use in artisanal gold mining on the ecological systems and the miners' health. 384 respondents were selected from artisans, minining rights holders, and local leaders. Data was collected using observation checklists, survey questionnaire, interview guide and documents review guide.

The findings indicated a strong correlation between the variables of interest determined using odds ration and 95% confidence intervals. It was established that, the mining communities live in deplorable sanitary conditions, use toxic chemicals such as mercury in the gold extraction process putting their health at a great risk.

In order to assess the relationship between the use mercury in gold extraction and ecological/health implications, all the factors that were significant at bi-variate level were subjected to a multivariate analysis using logistic regression model. The significant factors such as the implication of mercury use on land and water, miners' livelihood security and food production were fitted in the model and subjected to further analysis.

A Back Ward Stepwise Logistic Regression was used to control for all probable confounding variables in the test. The controls were done through model modification. The best logistic regression model fitted finally predicted the probability or chance that mercury use in gold extraction significantly affects the miner's health and ecological value.

Methodology

An exploratory cross sectional study design was used. The primary purpose of this study was to examine a largely unknown phenomenon, particularly the ecological and health implications of mercury use in artisanal gold mining. Quantitative methods were supplemented by a qualitative insight to provide significant understanding of the implications of mercury use in gold extraction.

The targeted study population was the household members and artisans involved in the artisanal gold mining in the districts of Buhweju and Mubende as well as registered mining rights. Particularly the categories of the population studied included; artisanal gold miners, mining rights holders in Mubende and Buhweju and other stakeholders within the gold mining sites. The study population comprised of 30 mining rights holds in Mubende, 21 mining rights in Buhweju, and a proportion of unlicensed artisans and other stakeholders in both districts. The sample size was calculated using the Kish and Leslie formula of random sampling for single proportion.

Sites and villages studied were purposively selected from the study districts using Simple Random Sampling method and data was collected using Focus Group Discussion Guides (FDGs), Survey Questionnaires, observation checklists, interview guide, transcription tapes, video tapes, and cameras.
A test-retest method was used to test for reliability. Pretesting was done to determine Cronbach's alpha; above 0.7; (Vogt, 2007 and Bougie, 2013); data was validated using sampling validity method.

Data was analysed using both qualitative and quantitative methods. Qualitatively; notes from the research assistants and transcripts from the tape records were compared, gaps filled and concise versions written out. The content and the emerging themes were recorded. The data was analysed using the descriptive master sheets. Quotations were used to keep the original concepts of the answers given. All data collected from various sources were triangulated during the analysis to complement, increase validity and check the oversights.

Quantitatively, data collected was sorted, checked for consistency and for completeness. Open-ended questions were categorized. After all data was collected, it was entered into SPSS software package and exported to Stata 8.2 software for analysis. The analysis was done in the following stages: Univariate analysis- where frequencies of variables were generated and tabulated in line with the objectives; At bivariate level/analysis, cross tabulations were constructed to establish the associations between variables of interest; At multivariate analysis, all variables that were statistically significant at bivariate analysis were subjected to the multivariate model to control for confounding and; The strengths of the association between variables were determined using odds ration and 95% confidence intervals.

Thematic review of Mercury use and its implications to human health and environment

Mercury is a metal characterized of being an odorless liquid at room temperature. It forms alloys (amalgams) with most metals, those with gold and silver being the most relevant. As a liquid metal, it is always in equilibrium with its vapor pressure, and hence, is easily volatilized. In nature; mercury is associated with other elements such as sulfur, for instance: sulphide class reddish mineral cinnabar, which is 85% mercury and 15% sulfur (mass).

Mercury is released into the environment both from natural sources (fires, faults and volcanic eruptions) and human activities (anthropogenic). Mercury has been used in many applications, including, but not limited to, various production processes where it is used as a catalyst in the chlor-alkali industry and in the production of vinyl chloride, for the extraction of gold, in electrical and electronic equipment and in measuring devices (e.g., thermometers, manometers gauges). Mercury can also be non-intentionally released from point sources such as smelting and roasting processes used in the production of non-ferrous metals, coal as a source of power, e.g., in power plants and industrial boilers.

Once mercury enters the environment as a pollutant, it is extremely harmful, given its persistence, mobility (in the atmosphere it can be transported over long distances), its ability to form organic compounds, to bio-accumulate (accumulating in living organisms) and to be bio-magnified (its ability to increase its concentration as it goes up in the food chain), as well as its negative impact on human health.

Damage to health and lives includes: permanent disruptions in the nervous system, with a particularly deleterious effect on the developing nervous system. Because of this, as mercury crosses the placental barrier and can be transferred vertically from mother to child during pregnancy, infants, children and pregnant women are considered to be the most vulnerable populations. There are many sources of mercury and complex transport and mobilization processes involved in the global mercury cycle.

In Uganda, in 2014, it is estimated that 60% of the current emissions to the atmosphere are from primary metal production, while 17 % come from waste incineration, and 15% comes from consumer products with the intentional use of mercury (NEMA, 2016)

In aquatic systems, atmospheric deposition is one of the most important pathways of the introduction of mercury; this is a process whereby chemicals are transferred from the atmosphere to the surface of earth. Mercury deposited in the soil may be partially carried to the local water system (through superficial runoff systems), however a considerable part is retained by plants and soil (Campbell et al, 2003).

Soils and sediments can also be significantly enriched in mercury as a result of isolated releases from local industrial facilities and other activities such as metal and gold mining. This mercury in soil and sediments is also a source of contamination of freshwater systems (rivers, lakes, creeks) through soil leaching and erosion, and through sediment suspension.

Globally, it is estimated that in 2010 the atmospheric deposition of mercury was 3,200 tons/year to land and 3,700 tons/year to the oceans. However, much of the mercury deposited both on land and in the oceans, is re-emitted to the atmosphere. A certain percentage of the mercury released into the aquatic environment is converted by microorganisms to methyl mercury (MeHg), which is more toxic and easily bioavailable than elemental mercury (Hg), staying in the environment, where it accumulates and biomagnifies in aquatic and terrestrial food chains (Global Alliance, 2009; UNEP,2013).

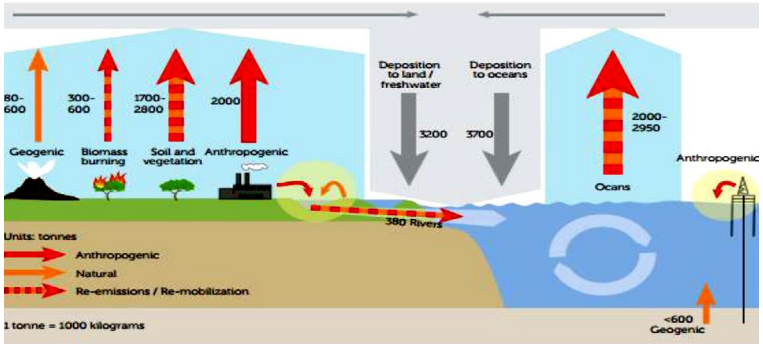


Figure 1: Source UNEP, 2013

Globally, the world's 10 to 15 million artisanal gold miners release about 1000 tons of mercury into the environment each year, or 35 percent of man-made mercury pollution (Clarkson et al, 2003). Artisanal gold mining is actually the leading cause of global mercury pollution, ahead of coal-fired power plants. Mercury is extremely harmful to human health. The amount of vapor released by mining activities has been proven to damage the kidneys, liver, brain, heart, lungs, colon, and immune system.

Chronic exposure to mercury may result in fatigue, weight loss, tremors, and shifts in behavior.
In children and developing fetuses, mercury can impair neurological development (Hentschel, 2002). It was established that two mining leases and 3 gold rush sites in the study reveal the use of Elemental Mercury. Gold ore rocks are worked on with steel balls that grind the ore into a fine flour. Mercury and gold bind as one, until, sundered by fire, the more volatile mercury is vaporized from the elemental union. In humans, approximately 80% of inhaled mercury vapor is absorbed via the respiratory tract where it enters the circulatory system and is distributed throughout the body. Chronic exposure by inhalation, even at low concentrations in the range 0.7–42 μg/m3, has been shown in case control studies to cause effects such as tremors, impaired cognitive skills, and sleep disturbance in workers (Hinton, 2011).
The organic forms of mercury, specifically methylmercury used in gold mining is of the greatest concern in terms of exposure from food. Metallic mercury discharged into the environment (air, water, tailings) from gold mining practices can be transformed into methylmercury, a readily bio available form of mercury. Due to its tendency to increase in concentration upward through aquatic food chains (i.e. it is biomagnified), individuals reliant on fish in mercury impacted areas may be at risk. Chronic exposure to moderate levels of methylmercury results in symptoms including: visual constriction; numbness of the extremities; impairment of hearing; impairment of speech; and impairment of gait. In cases of acute intoxication, muscular atrophy, seizures and mental disturbance are prominent. Women of childbearing age and their children are particularly susceptible, as methylmercury readily crosses placental barriers and is considered to be a developmental toxicant (Clarkson, 2002).

Elemental mercury is poorly absorbed by ingestion and skin contact. However it is hazardous due to its potential to release mercury vapor. Animal data indicate less than 0.01% of ingested mercury is absorbed through the intact gastrointestinal tract though it may not be true for individuals suffering from ileus. Cases of systemic toxicity from accidental swallowing of elementary mercury are rare, and reports of attempted suicide via intravenous injection did not appear to result in systemic toxicity. Though not studied quantitatively, the physical properties of liquid elemental mercury limit its absorption through intact skin and in light of its very low absorption rate from the gastrointestinal tract, skin absorption would not be high. Some mercury vapor is absorbed dermally, but uptake by this route is only about 1% of that by inhalation (Hinton, 2011).

Acute inhalation of high concentrations causes a wide variety of cognitive, personality, sensory, and motor disturbances. The most prominent symptoms include tremors (initially affecting the hands and sometimes spreading to other parts of the body),emotional labiality (characterized by irritability, excessive shyness, confidence loss, and nervousness),insomnia, memory loss, neuromuscular changes (weakness, muscle atrophy, muscle twitching), headaches, polyneuropathy (paresthesia, stocking-glove sensory loss, hyperactive tendon reflexes, slowed sensory and motor nerve conduction velocities), and performance deficits in tests of cognitive function.
Stress and sleep disturbance are some of the effects attributed to the miners by the use of mercury. But as you know, Gold Rush fever has several stresses associated to it. Even then, the sleeping quarters of canvass are vulnerable to sharp knives and razors of an intruder with wrong intentions, it would be careless to sleep with both eyes closed.

According to UNEP, an estimated 150kg of mercury is emitted into the environment every year. An estimated 45kg of this mercury may be discharged into small rivers and streams. It is also established that almost 90 to 100% of gold produced by small-scale artisanal miners is by mercury amalgamation. As observed in mining sites, the mercury danger is beyond the mining communities as some of this ends up in the rivers and lakes and is consumed by the rest of the population through fish or other aquatic foods. The World Health Organization states that exposure to mercury, even in small amounts, may cause serious health problems, and is a threat to the development of an unborn child and early in life. “Mercury

may have toxic effects on the nervous, digestive and immune systems and on lungs, kidneys, skin and eyes," and is considered by WHO as one of the top 10 chemicals or groups of chemicals of major public health concern.

In response to the international concern about mercury, and at the request by the UNEP Governing Council, the first global assessment of mercury and its compounds was published in 2002, in cooperation with other members of the Inter-Organization Program for the Sound Management of Chemicals.

As a result of this assessment, the Governing Council agreed that further international action was required to reduce the risks to human health and the environment. One of the main actions carried out in 2005 was the creation of UNEP's Global Mercury Partnership. The Partnership currently includes eight priorities or partnership areas, consistent with the major sources of mercury:i.e; Reducing mercury in artisanal and small-scale gold mining (ASGM); Mercury control from coal combustion; Mercury reduction in chlor-alkali; Mercury reduction in products; Mercury Air Transport and Fate Research Mercury waste management; Mercury supply and storage and Mercury reduction from cement industry (UNEP, 2008).

While chemicals demonstrate their usefulness in various aspects of our lives and economic activities, including healthcare and agriculture, our experiences of pollution-related illnesses such as Minamata disease and drug-induced suffering have also demonstrated that hazardous chemicals, if used improperly or released into the environment, may have significant negative effects on human health and the environment. Many of these problems caused by chemicals were previously seen as local or regional issues. However, the evolution of scientific knowledge has gradually revealed that chemicals may affect human health and the environment as they diffuse globally through atmospheric and oceanic circulation and via human activities such as international trade. Problems with chemicals are now recognized as issues that need to be addressed globally.

Mercury is also regarded as an issue that needs to be addressed globally. Since the diffusion of mercury is extensive, even a country where mercury emissions are negligible may be negatively affected by mercury emissions from other countries. Mercury pollution of lakes, rivers and, particularly, oceans is a global issue, raising concerns about its impact on the health of aquatic life and the organisms that consume it. Actually, mercury is detected at high concentrations even in the arctic region, which is distant from the emission sites. Although the amount of mercury used in developed countries is decreasing, a decline in mercury prices due to the decreased demand is leading to mercury use in developing countries for purposes for which alternatives to mercury are already available. International cooperation, including financial support and technological transfer, is necessary for the promotion of anti-mercury measures in developing countries.

Based on such an understanding, an intergovernmental negotiating committee (INC) with the authority to prepare a global legally binding instrument on mercury was established according to the 2009 decision of the Governing Council of the United Nations Environment Program (UNEP). The INC commenced its work in 2010 to conclude negotiations prior to the 27th session of the UNEP Governing Council in 2013 (UNEP 2013).

The text of the Minamata Convention on Mercury was agreed on by the fifth session of the INC in January 2013, and adopted by the Conference of Plenipotentiaries held in the city of Kumamoto, Japan, in October 2013. As of March 15, 2014, only the United States has ratified the Convention while many countries including Japan are preparing for the ratification of the Convention.

Uganda is yet to ratify the Minamata Convention after; assessing the national capacity and legislation and development of national mercury inventory on emissions and releases to the environment.

Findings on the Mercury use in artisanal gold extraction process

Mercury use in gold mining is not only a growing concern globally but also presents health and environmental here in Uganda. Mercury, a liquid metal, is used in artisanal and small-scale gold mining to extract gold from rock and sediment in many gold mining sites in Uganda. Unfortunately, mercury is a toxic substance that wreaks havoc on miners' health, not to mention the health of the planet (NEMA 2016).

Findings from the mining sites sampled in Mubende and Buhweju indicated that for every gram of gold produced, artisanal gold miners release about two grams of mercury into the environment. (Plate 1). Based on such an understanding, an intergovernmental negotiating committee (INC) with the authority to prepare a global legally binding instrument on mercury was established according to the 2009 decision of the Governing Council of the United Nations Environment Program (UNEP). The INC commenced its work in 2010 to conclude negotiations prior to the 27th session of the UNEP Governing Council in 2013 (UNEP 2013).

The text of the Minamata Convention on Mercury was agreed on by the fifth session of the INC in January 2013, and adopted by the Conference of Plenipotentiaries held in the city of Kumamoto, Japan, in October 2013. As of March 15, 2014, only the United States has ratified the Convention while many countries including Japan are preparing for the ratification of the Convention.

Uganda is yet to ratify the Minamata Convention after; assessing the national capacity and legislation and development of national mercury inventory on emissions and releases to the environment.

Plate1: Mercury on the Basin to be applied in the gold extraction



Majority; 347/384 (90.4%) of the respondents reported that they used Mercury in the gold extraction process. Of these, 88% reported health problems associate with the use of Mercury. 98% respondents expressed fears regarding the health and ecological implications of mercury use in gold extraction particularly the possibility of food and water pollution. Indeed observation revealed use of large amounts of mercury in the gold extractions. Besides, the mining sites were close to the water sources which accounted for 99% of water requirements for domestic use putting the health of the miners and the surrounding communities at a great health risk.

It was established that Mercury is the main chemical of Choice although Cyanide has been introduced. The soil is carted up from the mine below, the ores are run through a sluice to strain and separate large

rocks from small rocks. A few entrepreneurs have setup stone grinding machines but many miners have metallic mortars and pestles. They then centrifuge (Okuchanga) the fine rock dust in basins until such a moment that water from the soil is colourless and fine gold dust is at the bottom of the Omuchanga. The ore is then combined with mercury. After that, the floured concentrate is planned in a wide-lipped plastic basin, until what's left is the gold and mercury amalgam, ready to be burned.
Mercury and gold bind as one, until, sundered by fire, the more volatile mercury is vaporized from the elemental union.

According to Robert Sempebwa, the Chairperson of Singo Artisanal Small Scale Miners Association that has 1,250 members, all his members are not licensed. "Although we want to make these workplaces safer, we are not sure of tomorrow to invest such large sums of money," he says. The fact that they are unlicensed; they are not regulated by the Government and most of the time work practices are determined by different loose associations.

Mercury is added to all the ore being processed during crushing, grinding or sluicing. In most cases, only 10% of the mercury is added to an amalgamation barrel or pan (in case of manual amalgamation) combines with gold to produce amalgam. The rest (90%) is excess and must be removed and recycled or released into the environment, leading to widespread elevated levels in the atmosphere and severe health exposure problems for both miners and non-miners.

Panning, also known as gravity concentration of gold-bearing materials allows concentration of the gold with the heavier particles in the pan, while lighter particles are sluiced away. Mercury is then added to the concentrate to amalgamate or gather the fine gold particles. About 10-15% of mercury losses from Artisanal Gold Mining (AGM) are a result of this process. The Percentage of ore processed with mercury using amalgamation from concentrates varies from 30 to 100%. Women usually do the panning of the concentrate. Miners heat amalgam in a shovel or metal pan over an open fire to recover the gold. When this is done without the use of a retort, mercury vapor is released to the air and is inhaled by the miners and other people nearby.

Field inspections at the two mining leases and 3 Gold rush sites revealed the use of Elemental Mercury. Elemental mercury commonly called quicksilver (liquid metallic mercury) is one alternative to gold extraction. Gold ore rocks are worked on with steel balls that grind the ore into fine flour. Mercury and gold bind as one, until, sundered by fire, the more volatile mercury is vaporized from the elemental union. In Gold rush sites, mercury is supplied by the gold dealers who sell it expensively as mercury of 10,000/- is just a spoonful and is used to work on a basin load of soil. This soil to be mercury treated is washed several times until what is left is just a ladle sized quantity of fine sand. The washing removes all soil and since gold is heavy the miners believe the gold is contained in the last ladle of the washed soil. Then the gold dust and mercury form a strong union – Gold Amalgam. This marks the other dangerous phase of the exercise — roasting balls of amalgam composed of equal parts of gold and mercury.

Water contaminated with mercury presented potential affects to the environment and human health. Soil suspected to have gold is placed in a basin of water and mixed with one bottle of mercury. Mercury attracts all the gold particles in the soil. "In some sites, the gold deposits are located in water catchment areas and wetlands. Mercury is often improperly disposed of into wetlands. "Many of our valleys have been washed down with mercury, which contaminates our water" says one of the miners in Buhweju. It is a big challenge that needs to be addressed immediately," he noted.

In order to fully understand the implications of mercury use on environment and public health, bivariate analysis was used to examine the relationships as indicated below.

Table 1: Association of Chemical (Mercury) Use in Gold Extraction with Health Hazards

Used mercury in gold extraction	Health problems as a result of mercury use		Total	χ^2	OR	95%CI-OR	P-Value
	Yes	No					
Yes	73(94.8%)	265(86.3%)	338(88.0%)	4.0	2.89	1.41- 4.52	0.004**
No	4(5.2%)	42(13.7%)	46(12.0%)				
Total	77(100.0%)	307(100.0%)	384(100.0%)				

Use of mercury in gold extraction was significantly associated with miners' health. This is because the chi square value of 4.0 was greater than the hypothesized value of 3.864, 95% CI for odds ratio also never contained a one and the ρ-vale was less than 0.05, which all suggested a significant association between the practice of chemical use in gold extraction and the health problems.

Of the total 77 respondents who reported health problems, 94.8% (73) had used mercury in gold extraction as compared to only 5.2% (4) of the respondents who had not used mercury gold extraction. Looking at the odds ration value, one can conclude that using mercury in gold extraction was 4 times more likely to be associated with health and ecological problems as compared to non-use of mercury in gold extraction.

Table 2: Association of Mercury use in gold extraction with land degradation and water pollution

Used mercury in gold extraction	effect on land /water		Total	χ^2	OR	95%CI-OR	P-Value
	Yes	No					
Yes	170(80.6%)	265(86.3%)	311(80.9%)	8.4	0.941	0.41- 0.982	0.008**
No	41(19.4%)	32(18.5%)	73(19.1%)				
Total	211(100.0%)	173(100.0%)	384(100.0%)				

The practice of mercury use during mining was significantly associated with land and water pollution in the study area. This is because the chi square value associated with this test which is 8.4 is greater than the hypothesized value of 3.864 at 5% and the same conclusion can be arrived at by looking at the ρ-value of 0.008 which is less than the hypothesized test value of 0.05 which also suggests significance and the same conclusion can be arrived at by looking at the 95% CI for the odds ration value since it does not contain a one. Looking at the statistics, one can conclude that none use of mercury in gold extraction is 0.941 times less associated with land degradation and water pollutions as compared to use of mercury in gold extraction.

Table 3: Association of mercury use in gold extraction with food pollution/contamination

Use of mercury in gold extraction	Food pollution/contamination		Total	χ^2	OR	95%CI-OR	P-Value
	Yes	No					
Yes	196(80.5%)	128(92.4%)	324(84.4%)	9.6	0.4	0.02-0.74	0.002*
No	47(19.3%)	11(7.6%)	60(15.6%)				
Total	244(100.0%)	139(100.0%)	384(100.0%)				

Mercury use in gold extraction, as a mining practice, was significantly associated with food security particularly the food pollution/contamination along the chain. This is because the chi- square value of 9.6 was greater than 3.864 as is the rule and the p-value of 0.002 was less than 0.05 as the decision rule for significance and the same conclusion could be got by looking at the 95% CI for the odds ration value since it never contained a one.

Looking at the odds ratio value of 0.4, one can easily conclude that none use of mercury in extracting out gold was 0.4 times less likely to be associated with food pollution/contamination compared to use of mercury in the process of gold mining.

Written the other way, one can easily say that mercury use in gold extraction was 60% times more likely to be associated with food insecurity within the mining community particularly from the safety and quality point of view. Looking at the column percentages above, one can further see that of the total 244 miners who reported food insecurity, 80.5% (196) were in use of mercury in gold extraction as a mining practice as compared to only 19.3%(47) who were not using it.

Table 4: Association of mercury use in gold mining with Livelihood Security

Chemical Use	Has mercury use in gold mining affected your livelihood in any way		Total	χ^2	OR	95%CI-OR	P-Value
	Yes	No					
Yes	272(87.0%)	128(92.4%)	324(84.4%)	16.0	0.502	0.14-0.76	0.002**
No	41(13.0%)	5(7.0%)	46(12.0%				
Total	313(100.0)%	71(100.0%)	384(100.0%)				

The use mercury particularly in gold extraction influenced livelihood of the miners. This is because the test statistics like χ^2=16 was greater than 3.864, the p-value =0.002 was less than 0.05 and the 95% CI for this particular variable never contained a one.
In the overall opinion, mercury use in gold extraction was 48% times more likely to be associated with effects in miners livelihood as compared to its none use. If said the other way round, none use of mercury in gold extraction was 0.52 times less likely to be associated with effects in miners livelihood as compared to the use of mercury.
This can be future seen from column percentages where it's clear that only 13% of the total miners who reported an effect in their livelihood were not in use of mercury when mining as compared to 87% miners who reported an effect in their livelihoods and were found to be using mercury.
To further illustrate it, this means that mercury use in gold extraction process negatively impacted on people's livelihoods through affecting key livelihood indicators such as nutritional food values, income, water and food quality and health of miners. Thus, the use of chemicals such as mercury significantly affected the livelihood security of miners and that of the neighboring communities.

In order to confirm the relationship between the use mercury in gold extraction and ecological/health implications, all the factors that were significant at bi-variate level were subjected to a multivariate analysis using logistic regression model (Table 5). The significant factors such as the implication of mercury use on land/water, livelihood security and food pollution/contamination were fitted in the model and subjected to further analysis.

After all this was done, A Back Ward Stepwise Logistic Regression was used to control for all probable confounding variables in the test. The controls were done through model modification. The best logistic regression model fitted finally predicts the probability or chance that mercury use in gold extraction significantly affects the miner's health and ecological value. The model took the form as:

$$\text{Logit } (Y) = \alpha+\beta_1X_1+\beta_2X_3+\beta_3X_3+\beta_4X_4+\beta_5X_5+\beta_6X_6+.....+\beta_KX_K$$

Where logit PY is the probability that a miner's health and ecological value will be negatively affected. α is the Y intercept βi is the coefficient value of the likelihood confounders in the model. After adjusting for confounding at the multivariate level using log likelihood ratio, and model modification, all the variables that stood significance at bi-varaite, ended up being significantly associated with the mining practices in the absence of any confounder.

Table 5: Artisanal Gold Mining Practices and Livelihood Security Indicator Variables

	Variable	Response	Adjusted OR	95% CI Adjusted OR	ρ-Value
Use of Mercury in gold extraction					
1	Mercury use in gold extraction and health hazards	yes No	3.2	2.5-6.4	0.000**
2	Mercury use in gold extraction and environment degradation	yes No	0.61	0.2-0.94	0.001**
3	Mercury use in gold extraction and food pollution	yes No	0.42	0.14-0.82	0.000**
4	Mercury use in gold extraction and livelihood security	Yes No	0.50	0.12-0.70	0.000**
5	Mercury use in gold extraction and increased medical costs	Yes No	0.60	0.14-0.93	0.000**
6	Mercury use in gold extraction and effect on land and water	Yes No	9.40	4.80-12.6	0.000**

The conclusion of significance of all the variables was arrived at by looking at the corresponding ρ-values and comparing it with the 0.05. All the ρ-values for the different variables were less than 0.05 and so they were all significant.

Furthermore, the same conclusion was also arrived at by looking at the confidence intervals for the adjusted odds ratios as they did not contain a one as shown in that table above. The conclusion here is that, "there is a significant relationship between the use of mercury in gold extraction and the miners' health and ecological value.

Conclusion

The use mercury in gold extraction process was found to negatively impact on people's livelihoods through affecting key livelihood indicators such as nutritional food values, income, water and food quality and health of miners.

This was confirmed during the test for the relationship between the use mercury in gold extraction and ecological/health implications where all the factors that were significant at bi-variate level were subjected to a multivariate analysis using logistic regression model. The significant factors such as the implication of mercury use on land/water, livelihood security and food production/quality were fitted in the model and subjected to further analysis.

After adjusting for confounding at the multivariate level using log likelihood ratio, and model modification, all the variables that stood significance at bi-varaite, ended up being significantly associated with the mining practices (such as the use of mercury) in the absence of any confounder.

The conclusion of significance of all the variables was arrived at by looking at the corresponding ρ-values and comparing it with the 0.05. All the ρ-values for the different variables were less than 0.05 and so they were all significant.

Furthermore, the same conclusion was also arrived at by looking at the confidence intervals for the adjusted odds ratios as they did not contain a one. The conclusion here is that, "there is a significant relationship between the use of mercury in gold extraction and the miners' health and ecological value. That is to say, mercury in artisanal gold mining significantly affect miners' health and environment.

There is thus a need to regulate and formalize artisanal gold mining. Regulation and formalization of small-scale and artisanal gold mining will not only fetch government more revenue in terms of license fees and taxes, but also could also regulate the use of mercury and other environmentally-unfriendly mining practices and enhance sustainable exploitation.

Environmental health risks are likely to be exacerbated if no intervention is undertaken. For instance, if the prices of Mercury go down, miners shall be enticed to pour substantial amounts of mercury in less washed out ores. Instead of using it at final stages, miners will starting with the big ores where over 90% of the mercury is lost in soil and is easily lost into the ecosystem especially through run off soils.
In addition to mercury use in gold rush sites, it is believed that as activities in these sites subside, we may witness more clandestine gold amalgam processing in densely populated areas. Here family members especially children shall get exposed to the mercury vapours.

As small-scale gold mining expands in response to rising gold prices in Uganda bearing in mind that Gold and mercury are interdependent commodities, it is prudent to model responses to mercury poisoning and pollution. When the price of gold increases as it has since 2002 so shall mercury pollution, subsequently impacting negatively on public health and environment.

References

Campbell, L., Dixon, D. G., & Hecky, R. E. (2003). A review of mercury in Lake Victoria, East Africa: implications for human and ecosystem health. *Journal of Toxicology and Environmental Health*, Part B, 6(4), 325-356

Clarkson, T. W., Magos, L., & Myers, G. J. (2003). The toxicology of mercury—current exposures and clinical manifestations. *New England Journal of Medicine*, 349(18), 1731-1737

Clarkson, T W. (2002). The three modern faces of mercury. *Environmental Health Perspectives*, 110 Supplement 1:11-21.

Counter, S. A., & Buchanan, L. H. (2004). Mercury exposure in children: a review. *Toxicology and applied pharmacology*, 198(2), 209-230.

Collier, P. (2010).The Political Economy of Natural Resources. *Social research*, Vol 77:No. 4.

Hentschel. (2002). *Global Report on Artisanal and Small Scale Mining. Minerals and Sustainable Development Project*. IIED and WBCSD.

Hinton, J. (2011). *Baseline Assessment of the Mining and Minerals sector in Karamoja, Uganda: Development opportunities and constraints*. Ecological Christian Organization (ECO).

ILO. (2012). *Facts on Small-Scale Mining, Sustainable Development at Work*. World Summit on Sustainable Development.

MEMD. (2011). *Energy and Mineral Development joint Sector Review, Ministry of Energy and Mineral Development*. Ministry of Energy and Mineral Development, Kampala-Uganda.

NEMA. (2012) *National State of Environment Report for Uganda: Harnessing our Environment for Wealth Creation*.

NEMA. (2016). *Mercury Initial Assessment report: Identification of Challenges, Needs and Opportunities to implement the Minamata Convention in Uganda*.

UNEP (2012). *Analysis of formalization approaches in the artisanal and small-scale gold mining sector based on experiences in Ecuador, Mongolia, Peru, Tanzania and Uganda*. Retrieved from https://wedocs.unep.org/bitstream/handle/20.500.11822/11357/Formalization_Document_Final_June_2012.pdf?sequence=1&isAllowed=y

UNEP (2013). *Global Mercury Assessment 2013: Sources, Emissions, Releases and Environmental Transport*. Retrieved from https://wedocs.unep.org/handle/20.500.11822/7984

UNEP (2013). *Mercury Time to Act*. Retrieved from http://cwm.unitar.org/cwmplatformscms/site/assets/files/1254/mercury_timetoact.pdf

The Mercury Policy Project (2009). *Mercury rising: Reducing global emissions from burining mercury-added products*. Retrieved from http://www.no-burn.org/wp-content/uploads/MercuryRising_Feb2009.pdf