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Environmental Impacts of Artisanal Gold Mining on Surface Water Quality (Duking Gold Field, Todi District-Liberia 2017-2020)

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Abstract: ***Artisanal Gold Mining in Liberia and the world at large is a significant industry, providing employment directly and indirectly to people around the word including inhabitants of the Duking gold field vicinity and others part of Liberia as well. Interestingly; many ASGM operations occur near streams, rivers and other water bodies for easy access and washing of gravels which often result into environmental problems. Meanwhile; this research study conducted in the Duking gold field, Todi district-Montserrado, Liberia revealed that the concentration of heavy metals like, mercury and zinc were found above acceptable limit in the Kua River as per requirement of the Liberia Water Quality Standards, class II which is in alignment with the WHO standards. The Kua River which is the major source of water for more than two thousand people in the surrounding of the case study area reflects, water samples collected and analyzed recording high value of 0.002mg/L for Hg in sample 001, 0.016mg/L for Hg in sample 002 and 0.009mg/L for Hg in sample 003. While; Zinc recorded value was 2.71mg/L in sample 001, 2.13mg/L for Zinc in sample 002 and 1.95mg/L for Zinc in sample 003. As you may be aware, mercury has a long resident time in most environments and this makes its emission a threat to health and environment in a particular mining district. Moreover, inhaling large amounts of salacious dust, careless handling of mercury during panning and amalgamation of gold as well as the sharing of poor quality air are major causes of health hazard among miners and inhabitants. This research findings also revealed that the concentration of others heavy metals like, Iron, Lead and Cadmium value were found under an acceptable limit or level as per requirement of the Liberia Water Quality Standards (LWQS) Class II; which is in alignment with the WHO standards. However, Miners were thus advised to purchase protective gear like, dust masks, air filters and heavy chemical gloves for their personal use while on the mine. To conclude, the need for professional health and safety training is highly needed by miners and inhabitants of the mining district. Moreover, this research recommend that the division of Mines at the ministry of mines and energy need to strategize mechanism to improve the livelihood of local artisan-al miners in and out of the mining district, through specific mining techniques which must be in line with the mine law and contract of the Republic of Liberia.***

List of Abbreviations

ASGM	Artisanal Gold Mining
WHO	World Health Organization
EPA	Environmental Protection Agency
LWQS	Liberia Water Quality Standards
ND	Not Detected
P-S	Points used for Sample collections
P	Points only

1. Introduction of the research

Introduction

This paper is intended to provide thematic information on how the Artisan-al Gold Mining (ASGM) activities in the Duking gold field community, Todi district-Liberia has decline the surface water quality , the heath of miners and the environment as well.

Moreover; to identity the range of potential elements concentrated in the Duking River, like: Hg, Pb, Fe, and others parameters that are harmful to inhabitants of the area under study.

1.1 Geology of the study area

The geologic of Liberia which the Todi district and the Duking gold field are part of is underlain by Precambrian age rocks.

The entire country is section into three (3) major geological age provinces.

The Liberian age province that is dominate in the western part of the country is believe to be about (2700 m.a) and is said to be Achaean. While the eastern part of the country is eburnean and is said to be Proterozoic about (2300m.a), and in the southern portion is the pan- African age province which is about (550 m.a).

The boundary of the Pan- African deformation is the North-West trending Todi shear zone which comprises of series of south-west dipping faults associated with intense zone of mylonite (J.K Dorbor el at 2018).

According to (J.K Dorbor el at 2018), the Todi shear zone is a 400 km shear zone extending in to Liberia from Sierra Leone. In Liberia, it separate the granite and the greenstone Achaean rocks from neo Proterozoic granite and amphibolite rock, dating to the Pan- African .

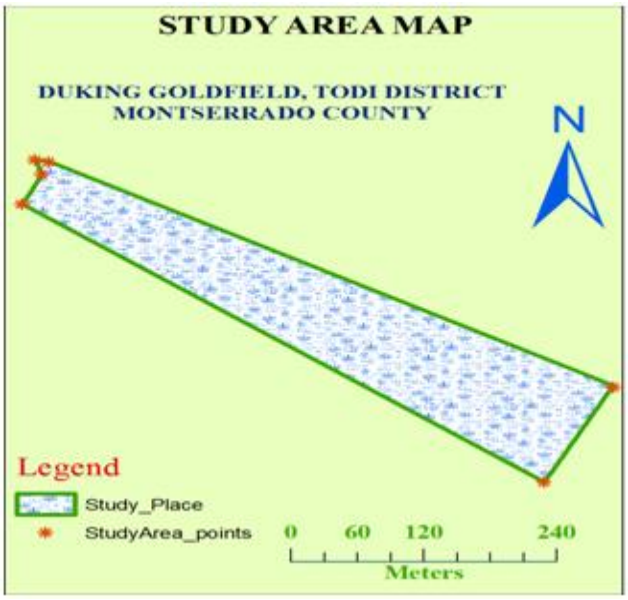

Figure 1: Location map of the study area, in the Todi district

1.2 Topography of the study area

The Duking gold field is characterized by highly undulating landscape which has a lot of greenish vegetation at the top of the area, and pockets of wetland surrounding the base of the mine. There were many Lithological units observed but not limited to, rose quartz, dolerite and spate of sedimentary composition.

Moreover; adjacent the mine is the Kua River that is about five (5) meters away from the immediate production site. The Kua River is the main source of water use by miners for the washing purpose of gravels for the recovery of gold. Meanwhile, the coloration of the Kua River depicts lot of environmental information as it relates to the poor methodology use in the extraction process of gold in the area.

On the other hand, the artisanal gold mining in rural areas Liberia and other parts of the country is an important sector for Economic growth. However, limited training and resources for extraction or processing of minerals are factors causing threats to both miners, local dwellers, and the environment as whole.

Finally; the main objective of this study is to understand the environmental impacts that artisanal gold mining has on surface water quality especially the Kua River, and this goal was absolutely archived.

1.3 Statement of the problem

This research was conducted due to the alarming poor health condition of inhabitants of the Todi distract-Liberia, especially the youth camp community which the duking goldfield is a part. Community dwellers are most often faced with constant health problem such as: Chronic cold, malaria, skill related diseases amid others.

Moreover; the poor health and living condition faced by the people of Duking Gold field area is shocking. Therefore, in order to understand the reasons and causes of these illnesses there is a need for an investigation to be conducted in order to find out the environmental impact of mining activities that is on going in the mining district with emphasis on their major source of drinking water that is being used.

1.4 Limitation of the study

During the research, some limitation was identifying for more work to be done in order for better data and scientific findings to be obtain about the area under study. The below is some limitation of this research but no limited to:

- Few samples were collected and analyzed due to insufficient finance,
- Limited number of parameters were found from the three samples collected due to laboratory constrain , and
- The study conducted cover an area of less than five square kilometer.

1.5 Research Questions

1) What is the threat of gold mining to inhabitants of the Todi-district?
2) What is the water quality like and what cause it?
3) What is the overall impact of mining on the environment under study?

1.6 Objective of the study

This research is intended to unveil findings about key water quality parameters, these key parameters become harmful when found above acceptable limits. Therefore, the understanding of how these parameters decrease the natural quality of the Kua River which serve as the main source of water for miners and inhabitants with in the study area in very important.

1.7 Significance of the study

The findings from this research is vital because, it enable geoscientists and others environmentalist to inferred the causes of the health problems faced by locals of the mining district. Moreover; based on the concentration of key water quality parameters found in various water samples collected and analyzed in the Environmental Protection Agency (EPA) lab in Liberia, interpretation and conclusion is Made to determining the source of these illnesses and others issues as well.

1.8 Definition of key words

1) Topography__ the feature of an area in terms of land scape.
2) Parameter ___ key elements of interest, Fe, Pb, etc.
3) ASGM _____ artisanal gold mining.
4) Concentration_ the amount or level of element presence in a medium.

1.9 Organization of the Paper

This paper is arranged in five major chapters. The first chapter is Introduction, giving the overview of what the research entails, the second chapter is the Literature review which provide literature related work as it relates to what

other researchers have done. While the third chapter is the methodology, providing the steps and technique used in getting results or findings and , the fourth chapter has to do with discussions and interpretations of the results. Finally, the last chapter of this work is the firth chapter which gives summary or conclusion and recommendation of the research work.

2. Literature Review

2.1 Introduction

According to an interview conducted with Miner (Peter Mulbah on the 22nd 0f may 2019),other miners use some chemical substances in the collection and processing of gold but for them they are not having ideals on how some go about doing search application. 'We at duking gold field make use of only water pump machine in washing our gravels during the processing and collection of our gold" said Peter Mulbah.

However**,** Mercury processing emits toxic vapors, with predicted global mercury emission by Artisanal Gold Mining (ASGM) to about 727 tones: 35% of the total world anthropogenic emission of mercury (UNEP 2013).

On the other hand, Artisanal Gold Mining (ASGM) is a globally significant industry, providing rural employment directly to at least 15 million people and indirectly to over 100 million in more than 70 countries (WHO 2013).

Again, although ASGM contributes to rural economies, but it often results in contaminated environmental, safety and social conditions due to the rudimentary mining and processing techniques used (Hilson 2002; Telmer and Veiga 2009).

Lindh (el al 2002), said Prolong exposure of mercury (Hg) may give rise to lunge damage, change in personality, restlessness, tremble, depression of sleep, and kidney problem. Similarly; Weiss (el al.2002), said that the main symptoms of Hg poisoning are nervous damage, numbness in the hands, feet, visual difficulty, and auditory symptoms. This thesis statement made by them was based on their methods and findings which the researcher of this paper is in alignment with because of what has been found during this study.

2.2 Conclusion

In conclusion, it is proven and backing my scientific result that the Duking Fild field which is undergoing study has some high concentrations of heavy metals that are above acceptable limit, specifically mercury and zinc. Based on the reality and findings, inhabitants of the area are subject to threat in terms of health and other environmental issues.

This happens when mercury form panning sites find it way in the Kua River through seepages and others means then finally into the river, where it is likely to be taken up by fish and other microorganism that are eatable by inhabitants.

3. Methodology

3.1 Field Methods

Introduction
This work, which was undertaken in the Duking Gold Field area incorporated visual observation, informal interviews, area mapping, samples collection, and sample analysis.

All raw samples were collected in a plastic rubber bottle on May 22, 2019 at the hour of 11: 30 am along the Kua River in the Duking Gold Field Community, Todi District. The first sample was collected along tributary within the immediate site of the mining area and the second sample was collected down the Kual River while the third sample was collected upper stream of the Kua River.

The table below showcases the coordinates of various point that were map during the study and those three areas where samples were collected form.

Table 1: Coordinates of various mapping point

Points & Samples ID#	X	Y	Sample volume	Descriptions
P_S 001	0330328	0717467	**500ml**	Sample collected along Tributary, down Kua River
P- 002	0330265	0717350		Mapping coordinate, Down the mine
P_S 003	0329816	0717731	**500ml**	Sample collected along Mid part of Kua River
P- 004	0329798	0717694		Mapping coordinate ,Mid part of Kua River
P- 005	0329822	0717746		Mapping coordinate, Upper part of Kua River
P_S 006	0329810	0717749	**500ml**	Sample collected along the Upper part of Kua River

These samples were collected, labeled and described in the field, packed and transported to the Environmental Protection Agency (EPA) laboratory 3rd street sinkor Monrovia city-Liberia. While in the field mapping and doing geologic investigation of various site, strategic areas in the vicinity of the mine camp were identify for the collection of the three major samples that was used for the facts findings.

During that, a germa-xtra GPS was use in the mapping of the study area and also for the collection of various samples. The pictorial representation below show case various areas that were mapped during the research period.

Figure 2: Pictorial representation of mapping and samples collection.

3.2 Laboratory methods

The three raw samples collected on the 22nd of May 2019 were submitted on the 23rd of May 2019 about 12:00 pm.

Moreover; all surface water samples collected, labeled, and submitted to the Environmental Research & Standards Laboratory (EPA) were analyzed for key water quality parameters, namely: pH, Iron, Mercy, Lead, Cadmium and Zinc. During the analysis of pH; which tells the acidity or basicity of a water, the pH-meter was used during the study. On the other hand, photometry was used to analyze for the iron (Fe) concentration in the various samples. Cold vapor method which is one of the most acceptable technique use in detecting the concentration of Mercury(Hg) was use for analyzing the presence of mercury during the research. While lead (Pb), Zinc (Z) and calcium (Ca) presence were detected by using spectrophotometry methodology.

In conclusion, it is owning to the fact that because of these methods and instruments used during the analysis of various samples the data and results generated for scientific interpretations are found below.

4. Result and Interpretation

4.1Result

This study was meant for a rapid assessment of heavy metals presence in the Kua River along the Duking gold field area as the results of the past and present mining activities. They were selected because of their known toxicity and threat to human and the environment in similar mining districts.

Therefore; based on the various methodologies employed during the laboratory analysis, the below findings were discovered.

Table 2: Gives the concentrations of each parameters and acceptable H_2O Quality Standards.

Result of Water Analysis

Parameters	units	methods	S-001	S-002	S-003	LWQS Class II
pH	-log H	pH Meter	7.91	7.79	7.68	6.0-9.0
Iron	mg/L	Photometry	0.90	0.99	0.91	1.5
Mercury	mg/L	Cold Vapor	0.002	**0.016**	**0.009**	0.005
Lead	mg/L	Spectrometry	0.04	0.03	0.06	0.1
Cadmium	mg/L	Spectrometry	0.003	0.007	0.006	0.01
Zinc	mg/L	Spectrometry	**2.71**	**2.13**	1.95	2.0

Note: Values in **bold** are above limit; ND=not detected, LWQS=Liberia Water Quality Standards.

4.2 Interpretation of results/ findings

The Chemical analysis of water samples collected from tributary and along the Kua River indicated high level of mercury and zinc (Figure 4). Sample number two and three recorded value of 0.016mg/L Hg for sample#002 and 0.009mg/L Hg for sample #003, which was the highest mercury concentration value detected in the area. While, sample#001 and sample#002 recorded value of 2.71mg/L for Z in sample-001 and 2.13mg/L for Z in sample-002. On the other hand; according to the research findings obtained, the concentration value of pH in the all samples: S#001=7.91mg/L, S#002=7.79mg/L and S#003=7.68mg/L which prove to be acceptable by the LWQS Class II.The concentrations value of Iron (Fe) in the three samples were S#001=0.90Mmg/L,S#002=0.99mg/L,S#003=0.91. In addition to Fe, and Cadmium, Lead value wasfound to be : S#001=O.04gm/L, S#002=O.03 and S#003=0.1 for Lead.

4.2.1 Graphical representation of results from sample-001

The findings from sample no. 001 reflects and indicate that parameters like: pH, Iron, Mercury, Lead, and Cadmium were found under an acceptable limit value as per the requirement of the Liberia Water Quality Standards Class II, in alignment with WHO standards.

However, **Zinc** was the only parameter found above the acceptable limit with a high value of **2.71mg/L.**

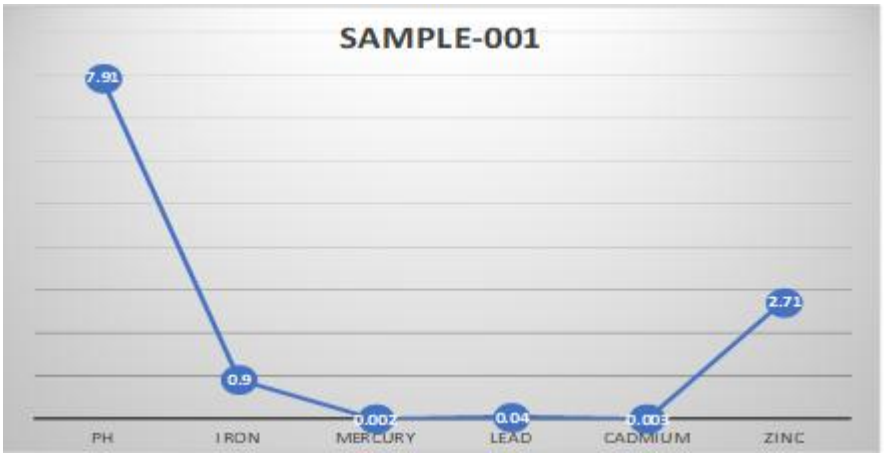

Figure 3: Showcase the concentration of each parameter in sample 001

4.2.2 Graphical representation of results from sample-002

The findings from sample no. 002 reflect also that parameters like: pH, Iron, Lead, Cadmium, were found under an acceptable limit value as per the require standards from the Liberia Water Quality Standards Class II, in alignment with WHO water quality standards as well.

Mercury and ***Zinc*** were found above acceptable limit value, this reflect a serious threat to inhabitants and miners in the area as well. The presence of Mercury and Zinc in the Kua River that is use by more than two thousand persons of the Duking Gold field, reflect danger as the result of the presence of these metals.

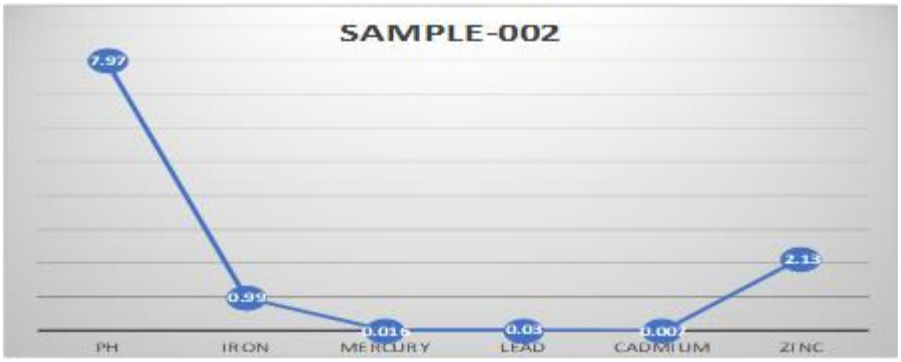

Figure 4: Showcase the concentration of each parameter in sample 002

4.2.3 Graphical representation of results from sample-003

The findings from sample no. 003 indicate that key parameters like: pH, Iron, Lead, Cadmium and Zinc were also found under an acceptable limit value, as per the standards of the Liberia Water Quality Standards in alignment with WHO water quality standards.

But it was noted by findings that ***Mercury*** concentration was above the acceptable limit with value of 0.009 mg/L in the Kua River.

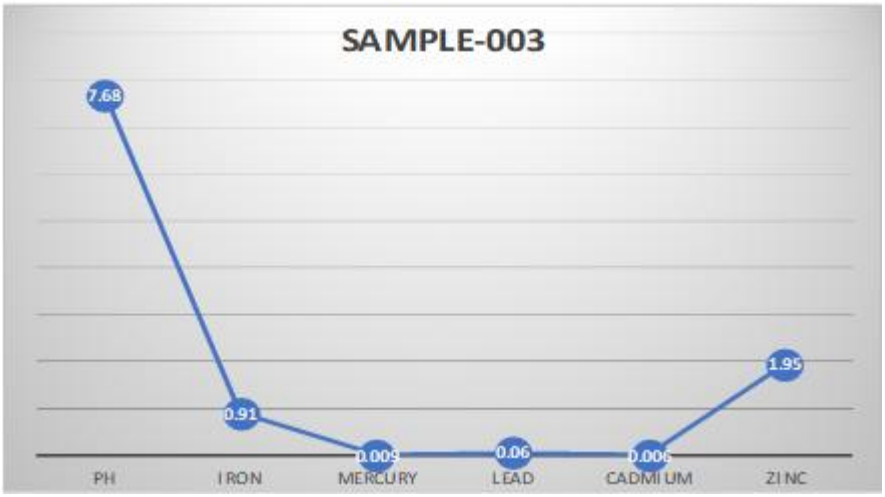

Figure 5: showcasing the concentration of each parameter in sample 003

4.2.4 Summary of graphical representation of the various results

These three graphical representations above displayed the level or limit of each parameters that were presence in various samples during the laboratory analysis. Graph one displayed that only **Zinc** was found above acceptable limit and others parameters (Lead, Mercury, Cadmium and even pH) were found in an acceptable limit. Similarly; graph two also graphically explain that Mercury and Zinc were the two major parameters found above acceptable limit as per the Liberia Water Quality Standards (LWQS) class II. On the other hand, graph three which is the last representation of the three samples depicts that Mercury was absolutely the only parameter that was detected with high concentration above the acceptable level of mercury presence in a usable water.

Finally, the high concentration of mercury and zinc found in these samples collected from the Duking Gold field vicinity depict threat to the environment and even residents of the mining district.

5. Discussion, Conclusion and Recommendations

5.1 Discussion

The Relationship between mining and the environment are particularly complex and not yet fully understood especially in underdeveloped areas or countries. Artisanal gold mining is a dangerous activity as heavy metals mainly Hg, Pb, and Fe are released to the environment during mining activities.
The environmental consequences of mining in the Todi District came to the full attention of people only recently when skin diseases, chronic cold, malaria and even numbness in the feet were frequently being reported, moreover decline in the Kua River water quality as the result of mining activities in the Duking Gold field area were also a key issues during the report.

Miner (Peter Mulbah) in an interview said; the main health problem in the mining district include but not limited to: Skin diseases, malarial, chronic cold and others illnesses.

According to research findings during the study, it was proven that the presence of heavy metal like, Mercury and Zinc were found above acceptable limit.

Similarly; according to the United State Agency for Toxic Substances and Disease Registry (ATSDR 1999) Pb and Hg top the priority list of hazardous substances. The first two are major in gold sulphide deposits, where they occur as minerals in Arsenio-pyrite (FeAsSs) and galena (Pb S), respectively. Under natural conditions, they are relatively stable.

However, once mining has taken place the minerals are broken down due to exposure to oxygen and water. Hence, the main problem for identification of heavy metal poisoning is that typical symptoms of poisoning are often masked by microbial and parasitic infections, malnutrition and poor living conditions and medical care (Harada, 1996).

Finally, it can be inferred that the bad health condition of inhabitants in the mining district may be attributed to the presence of these heavy metal in the Kua River, which is in confirmation as per laboratory results and even responses gather from inhabitants including what miner (Peter Mulbah) said in an interview with him on May 22, 2019 about 10:00 AM.

5.2 Conclusion

As you may be aware, mercury has a long resident time in most environment and this make its emission from artisanal mining a threat to health. Moreover, inhaling large amounts of salacious dust, careless handling of mercury during panning and amalgamation of gold as well as the sharing of poor quality air are major causes of health hazard among miners and inhabitants

This research study conducted in the Duking gold field, Todi district revealed that the concentration of heavy metals like, mercury and zinc were found above acceptable level. The water samples collected and analyzed recorded value of 0.002mg/L for Hg in sample#001, 0.016mg/L for Hg in sample#002 and 0.009mg/L for Hg in sample #003.While Zinc recorded value of 2.71mg/L for Zinc in sample#001, 2.13mg/L for Zinc in sample#002 and 1.95mg/L for Zinc in sample#003.

This research findings also revealed that the concentration of others heavy metals like, Iron, Lead and Cadmium value were found under an acceptable limit or level as per requirement of the Liberia Water Quality Standards(LWQS) Class II in alignment with the WHO standards.

However, Miners were thus advised to purchase protective gear like, dust masks, air filters and heavy chemical gloves for their personal use while on the mine.

5.3 Recommendation

a) Providing technical and professional training for miners so as to improve their skills in mining and gold processing
b) Providing training in mine safety.
c) Campaigns on public healthissues in the vicinity**.**
d) Avoid the use of mercury for the amalgamations of gold in and around the study area.
e) The building of pit latrine for works and inhabitants
f) Use of underground water for household purposes.
g) Sensitization on harm of key parameters found above limit and
h) Finally, take precautionary measures

Acknowledgement
The author of this paper is please to lengthen thanks and appreciations to the almighty for his abundance blessing upon this research project. Sincere thanks also go to all staff of the Department of Geology headed by Mr. Anthony Kullie chairperson of the Department of Geology University of Liberia (UL) for the exposure of the author to the geoscience society of Liberia, the world at large and this research paper as well.

The author is also indebted to Mr. Rafael Ngumbu, Lab supervisor at the Environmental Protection Agency (EPA) Liberia and analytical chemist of the University of Liberia for supervising the Laboratory section of this project.

This paper is based on research findings of a project in the Duking Gold Field area, Todi District which was sponsor by Mr. and Mrs. Joseph N. Kamara of the Association of Career Development (ACD) - Bong County, Liberia.

Moreover, I would like to recognize the following astute personalities for the technical and financial assistances render during the preparation of this research project:

Mr. Mr. Richard Y. Mulbah of the Environmental Protection Agency (EPA) of Liberia and Ms. Kebeh B. Kamara, of the Liberia National Fire Service for her astute financial role.

Above All, I give glory and honour to God!!!!

DECLARATION

I hereby declare that the work done in this thesis is my own and has not been submitted for any degree or examination in any college or university. In view of the above, some cases where others people ideas and papers were used, they have closely been acknowledge by sincere references.

Full name of student:
Joe B. Kamara, ID#**: 80375**

Signature _____

Date _____

DEDICATION

I dedicate this thesis to **Mr. Johnson Wolabo**, Assisting Minister for Planning at the Ministry of Mines and Energy.

May God richly bless you!!!!!!!!

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APPENDIX A: **Questionnaire for miners and inhabitants of the district**

Dear Sir/ Madam:

This questionnaire is meant to assess important information about how the artisanal gold mining activities in the Duking gold field, Todi district has on the water quality and the environment as well.

The information is specifically for study purpose and it's sincerely confidential. Your fair response is highly appreciated.

Name ----------
Contact ----------
Age ---------- and Sex ----------

When did you/ people started mining in this area ----------?
What is the frequent health problem faced with miners----------?
What is the main source of water use for washing of gravels----------?
What do you people use to recover the gold out of the gravels----------?
How many persons are working in this mine camp----------?
Are there any government/NGO initiative to improve the industry in terms?
(a) Awareness/ Sensitization
(b) Funds
(c) Another way
Final comment, if any ----------

APPENIX B: Sample Collection and submission log sheet

Sample collection log

Date: _____
Time: _____
Sample ID: _____
Sample coordinates: _____
Sample volume: _____
Field description if possible: _____
Comment: _____

Sample submission log

Date: _____
Sample pH: _____
Mercury concentration: _____
Iron concentration: _____
Lead concentration: _____
Cadmium concentration: _____
Zinc concentration: _____

Comment from Lab: _____