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Preliminary Study on Heavy Metals Levels in Soil and Water of Abandoned Gold Mining Areas in Banmauk Township

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ဗန်းမောက်မြို့ ရွှေသတ္တုတူးဖော်ထားရှိခဲ့သည့် နေရာများ၏ မြေဆီလွှာနှင့် ရေတွင် သတ္တုအဆိပ် အတောက်များပါဝင်မှုအခြေအနေအားပဏာမဆန်းစစ်လေ့လာခြင်း

ဆွေဆွေထွန်း၊ လက်ထောက်သုတေသနအရာရှိ

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ခရစ္စတီနေဝင်း၊ လက်ထောက်သုတေသနအရာရှိ

စာတမ်းအကျဉ်း

ဤသုတေသနစာတမ်းသည် ဗန်းမောက်မြို့နယ်အတွင်းရှိ ရွှေသတ္တုတူးဖော်ထားရှိခဲ့သည့်နေရာများအနီးရှိ မြေဆီလွှာနှင့်ရေတွင်သတ္တုအဆိပ် အတောက်များပါဝင်မှု အခြေအနေကို လေ့လာထားခြင်း ဖြစ်ပါသည်။ အချို့သော သတ္တုအဆိပ်အတောက်များ - ခဲ(Pb) ၊ ကော့ပါး (Cu)၊ ခရိုမီယမ်(Cr) ၊ နီကယ်လ်(Ni) နှင့် ပြဒါး(Hg) ဒြပ်စင်များ ပါဝင်မှုအား ၂၀၁၇ခုနှစ်တွင်ကွင်းဆင်းနမူနာစုဆောင်း၍ဓါတ်ခွဲစမ်းသပ်ခဲ့ပါသည်။ ရွှေသတ္တုတူးဖော်ခြင်း မရှိသည့် မြေနေရာများ၏ မြေဆီလွှာတွင် သတ္တုဒြပ်စင်များ ပါဝင်မှုသည် ကမ္ဘာ့စားနပ်ရိက္ခာ အဖွဲ့(WHO)၏ သတ်မှတ်ထားသည့်ပမာဏအတွင်းပါဝင်ပြီး သတ္တုညစ်ညမ်းမှုအညွှန်းကိန်း အရ မြေဆီလွှာညစ်ညမ်းမှု မရှိကြောင်း တွေ့ရှိရပါသည်။ ရွှေသတ္တုတူးဖော်ထားရှိခဲ့သည့် နေရာများရှိ မြေဆီလွှာတွင် အထူးသဖြင့် ကော့ပါးနှင့် နီကယ်လ်ဒြပ်စင်များ အမြင့်ဆုံး ပါဝင်ပြီး အသင့်အတင့် မှ အများဆုံးညစ်ညမ်းမှုအခြေအနေရှိပါသည်။ ရွှေသတ္တုတူးဖော်ခြင်း မရှိသည့်နေရာများရှိ ချောင်းရေနမူနာများတွင် ခဲဒြပ်စင်မှလွဲ၍ ကျန်ဒြပ်စင်များသည် သောက်သုံးရေပမာဏအတွင်းပါဝင်ပြီး သတ္တုတူးဖော်ခဲ့သည့် ရေစစ်ကန်များရှိရေနှင့် အနီးရှိချောင်းလက်တက်များတွင် - ခဲ ၊ ကော့ပါး၊ ခရိုမီယမ်၊ နီကယ်လ်နှင့် ပြဒါး ဒြပ်စင်များသည် သတ်မှတ် ပမာဏအထက်တွင်ရှိပြီး ရေအရည်အသွေးပြဿနာရှိကြောင်း တွေ့ရှိရပါသည်။ ကောက်ယူစုဆောင်းခဲ့သည့်ဒေသ၏ရေနမူနာများတွင် ခဲနှင့်နီကယ်လ် ညစ်ညမ်းမှု အများဆုံး ဖြစ်ကြောင်းတွေ့ရှိရပါသည်။ သတ္တုညစ်ညမ်းမှုနှင့် ပတ်သက်၍ အခြားသော သုတေသန ဆန်းစစ်ချက်များလိုအပ်သော်လည်း ယခုလေ့လာတွေ့ရှိချက်သည် ရွှေသတ္တုတူး ဖော်ထားရှိ ခဲ့သည့် နေရာများအနီးရှိ မြေဆီလွှာနှင့် ရေတွင် သတ္တုအဆိပ်အတောက်များ ပါဝင်မှု အခြေအနေအား ပဏာမလေ့လာဆန်းစစ်ချက်အဖြစ် သတင်းအချက်အလက်များ ထောက်ပံ့ ပေးနိုင်ပါသည်။

Preliminary Study on Heavy Metals Levels in Soil and Water of Abandoned Gold Mining Areas in Banmauk Township

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Abstract

The present study is to assess soil and water with special concern to heavy metal contaminations/pollution in the vicinity of abandoned gold mining areas in Banmauk township. The study was implemented in September, 2017 and some heavy metals (Pb, Cr, Cu, Ni and Hg (except Hg in soil) were determined. Heavy metals concentration in soil of mine-outside or undisturbed areas are within WHO limits and metal pollution index values are unpolluted under the Igeo Index value. Abandoned mine sites have high risk of accumulating heavy metal especially for Pb and Ni, and Igeo value are moderately to strongly polluted. Heavy metal concentrations in surface stream water are within WHO recommended limit for drinking water, except Pb. Concentration of Hg, Pb, Cu and Ni in water in mind ponds and water inlets in abandoned areas are above WHO limits and thus poses a quality problem. Average (Igeo) value of Ni and Pb in most of the waters in the study area are extremely contaminated. The current study only provides preliminary information on heavy metal levels in soil and water from abandoned mining areas, further broad studies are needed.

Keywords: Heavy metal, WHO limits, Pollution

Preliminary Study on Heavy Metals Levels in Soil and Water of Abandoned Gold Mining Areas in Banmauk Township

1. Introduction

Myanmar holds diverse mixes of rich natural and mineral resources with a total land area of 676,578 sq km. The mining sector contributes to the economic development of the country through foreign exchange earnings, employment and improved standard of living.

Focus in the mining sector should not be only on the economic aspects, but on sustainable environmental management, which is part of the integrated global efforts for environmentally friendly production processes. (Asantael Herman1, Charles Kihampa, 2015).

To ensure food security with increasing population, small scale gold minings are still adopting in gold deposited areas which has not been undertaken in a sustainable way although new mine todays are restricted environmental control. Local community used different methods of gold mining which include mechanized mining, mercury and cyanide chemicals to produce more and more gold.

During gold extraction, Significant heavy metal pollutants like Cd, As, Cu, Hg of toxic discharges and other trace elements can be uncontrollably percolated and penetrated to the soil and creating water and groundwater pollutions.

The concerns over the negative environmental impact of mining and the associated activities are not only for the operational periods but more importantly also on the effects even years after mining activities have ceased. One of the major concerns is the mine tailings, which is waste from mines after the ore has been extracted and is generally toxic. Although mining activities may affect relatively small areas, they could have significant impact on the environment. (Mileusni´ c, M.etal., 2014)

Efforts have been made on environmental risk assessment in gold mining area however; detail research study involving investigation and environmental risk of soil and water quality need to be strengthened in designing the management and conservation programmers in the small scale mining areas.

2. Objectives

- To investigate soil and water contamination in small scale gold mining area
- To provide technical information for effective management strategies of small scale mining areas.

3. Literature Review

Mining operations disturb the surface topography and remove vegetation, cause excessive erosion. Open cast mining involves the excavation of large quantities of waste rock (material not containing the target mineral) in order to extract the desired mineral ore. The waste rock and the exposed bed rock walls from which it is excavated are the source of most of the metal pollution caused by mining (Carlos and James, 1997). The improvements of mining practices significantly increase the environmental risks. Industrialization and mining operation play vital role in the overall development and progress of any region.

Along with the development, the increasing numbers engaged in ASM, use of mechanized mining, mercury and cyanide in gold mining, environmental and social impacts became an increasingly serious pollution problem. The industry's trend to shift from underground to open cut methods, along with mining of low grade ore deposits generate larger amounts of waste rock and tailings from the processing plants.

The mine drainage contains high concentrations of metals and metalloids which increase minerals contents in ground water and soil might be one of major pollution sources. The release of mining waste to the environment can be caused in intense destruction of ecosystems, which, in some cases, may not be fully restored or rehabilitated. (Halim M. et.al., 2012)

The presence of toxic metals in soil can severely inhibit the biodegradation of organic contaminants (Kirpichtchikova T. et.al, 2006) Heavy metal contamination of soil may pose risks and hazards to humans and the ecosystem through: direct ingestion or contact with contaminated soil, the food chain (soil- plant-human or soil-plant-animal-human), drinking of contaminated ground water, reduction in food quality (safety and marketability) via phyto toxicity, reduction in land usability for agricultural production causing food insecurity, and land tenure problems. (MJ McLaughlin et.al, 2006).

Some of the heavy metals such as Cu, Fe, Ni and Zn are essential micronutrients for animals and plants but are dangerous at high levels, whereas Cd, Cr, Pb and Co have no known physiological functions but are detrimental at certain limits. Furthermore Cr, Cd and Ni are carcinogenic, while Pb may cause neurological impairment and central nervous systemmal functioning. Mercury is used to recovery gold in the gold production process. Miners and their families often inhale toxic mercury vapors through this gold mining process and mercury can pollute homes and communities. Mercury could be inhaled and absorbed through the body skin. The mercury could be toxic in the form of organic compounds as well as inorganic compounds. Mercury could cause chronic as well as acute poisoning. River and lake water in the nearby industries may contain mercuric discharges which are fatal for the aquatic as well as human life. These discharges could accumulate in the stomach and remain non-digestible resulting in the formation of cancerous diseases. Long time exposure to mercury could cause serious damage to nerve, brain, kidney, lung irritation, eye irritation, skin rashes, vomiting and diarrhea.

4. Materials and Method

4.1 Sampling sites

The study area was located at small mining areas demarcated in the Bamauk Township, Kathar District, the north-eastern part of Myanmar . The study area falls within the coordinates of 24.535829 to 24.600396 N and 95.937429 to 95.90085495 E . The area has a tropical climate and average rainfall is 993mm, the average temperature is 19 ºC. The soils of the study area belong to xonthic Ferrasol order. The mining operations in the past were digging holes, crushing and grinding of ore, washing and trapping of gold minerals using sluice tables, amalgamation and burning activities and finally gold recovery in tailings using mercury and cyanide in leaching tanks. The choice of the sampling points took into account location, accessibility, proximity to communities' areas and the adjacent outside area of the gold mine.

4.2 Sample collection

In this study, soil and water samples were collected in the vicinity of abandoned gold mining sites and their processing units along the Maezar chaung. Field sampling was conducted in September 2017.The sampling sites are described in Table 1 and indicated in the map in Figure 1. The indication of sampling sites in the area was enable by Global Position System (GPS) points that were measured during sampling.

Table 1. The sampling site of study area

Soil/water sample	Description of location	lat	long
S1/W1	undisturbed area/ stream	24.535829	95.937429
S2/W2	mine-outside area/ stream	24.543993	95.948589
S3/W3	mine-outside area/ stream	24.547974	95.936977
S4/W4	mine-outside area/ stream	24.568253	95.936585
S5/W5	abandoned mine/ Water inlet	24.595643	95.910452
S6/W6	abandoned mine/ Mine pond	24.597938	95.890600
S7/W7	abandoned mine/ stream inlet	24.599854	95.896698
S8/W8	Active mine/ Mine pond	24.600396	95.900854

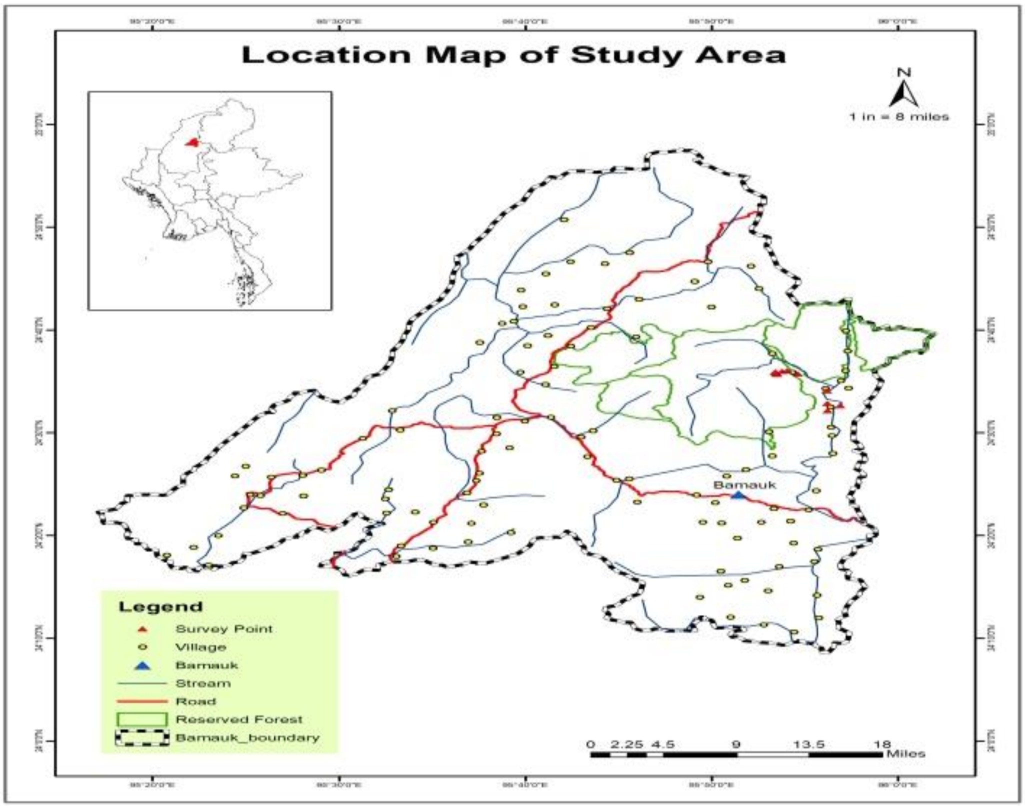

Figure 1. Map of study area

Soil samples were collected from 8 sites which comprise of 1 undisturbed or natural vegetation, 3 mine outside areas, 3 abandoned mines and 1 active mine (S1-S8) at the depths of 0 to 15 cm. Three soil samples from each sampling location were randomly collected and polled together to form a composite from each of the sample location. The collected samples were stored in polyethylene bag and labeled properly and taken to the soil laboratory. General physical and chemical properties are analyzed in Forest soil Laboratory.

A total of eight water samples (W1-W8) were collected with three replicates from different sources to include 3 stream water, 2 mine ponds and 2 water inlets in the vicinity of mining. The sample bottles and caps were rinsed three times with the water to be sampled prior to sampling and then immersed below the water level until they were completely filled. Then the samples were acidified with 1% nitric acid (HNO3) for preservation and stored (USEPA, 2008). After that the samples were measured for pH, and EC, and alkalinity using a robot technique in water laboratory of FRI.

The heavy metal content in soil and water were determined by using AAS spectrometer and X-ray Spectrometer Photometer in Land Use Department and Nanova Company. The results obtained were compared with the World Health Organization (WHO, 2006)

4.3 Data analysis

Data generated from the laboratory was subjected to descriptive statistics of standard deviation which were achieved using Microsoft excel for data entry, Advanced Statistical Assessment (ASA) was used for mean, range and standard deviation. The data for the soil and water samples were used SPSS Software to ascertain the accuracy and validity of the results from the study area.

5. Results

5.1 Physicochemical Properties of soil

The results of the physicochemical analysis of soils from study area are shown in Appendix 1. The soil reaction varied from slightly acidic to alkaline reaction with a pH values ranged from 6.0.to 8.0.The percentages of particle size distribution in the sample soil were in the range 2 to 11, 7 to 22 and 58 to 83% for clay, silt and sand respectively. The textural class at mine site was loamy soil to sand condition while that at undisturbed or mine outside area was sandy loam. Generally, concentrations of total nitrogen and organic matter in control areas were more than active or abandoned sites but available phosphorus and exchangeable potassium are not different.

5.2 Physicochemical Properties of water

For water sample, physical parameter includes only turbidity while chemical parameters include pH and alkalinity were measured and presented in (Appendix I).

The level of turbidity in water samples are ranged from 3.34 FNU to 1063.6 FNU. Mean level of turbidity in W6 to W8 sampling points exceeded the maximum admissible limit for drinking water quality set by WHO.

In the present investigation, pH was alkaline values; ranges from 7.94 to 8.05 (Average: 7.85). The maximum pH value was recorded in W8 and minimum in W3. On an average, the results of water samples showed that alkaline nature. The results indicated all the samples are complied with WHO desirable limit (6.5-8.5 pH)

The value of alkalinity of water samples was found to be ranges from 63mg/L to 77 mg/L (Average 71.6 mg/L) which were showing within the desirable limit.

5.3 Heavy metal concentration in soil

This study has shown active and abandoned areas are significantly different in terms of heavy metals contents than the other sites and shown in Appendix II

Table 2 present mean of heavy metals (Cu, Cr, Pb and Ni) concentrations (mg kg^{-1} soil) in the soils of the study area.

Table 2. Heavy metal concentration in soil

Soil sample	Ni mg kg^{-1}	Cu mg kg^{-1}	Pb mg kg^{-1}	Cr mg kg^{-1}
S1	23.4	11.5	7.0	0.1
S2	33.7	14.3	5.7	0.2
S3	23.0	1.4	1.5	0.1
S4	18.9	22.3	2.0	0.2
S5	77.8	56.8	90.3	1.3
S6	55.7	48.6	96.3	0.2
S7	85.6	47.2	86.8	1.0
S8	70.4	49.6	89.0	1.4
WHO (1996)	35	36	85	100

The concentration of Ni in soil in all sites varied between 18.9- 85.6 mg/kg. The permissible limit by WHO (Table 2) is 35mg/kg, the concentration values of S1, S2,S3 and S4 were within the permissible limit but the other points were higher than recommended limit.

Coppers concentration in soil ranged between 1.4to 56.8 mg/kg. The permissible limit according to WHO standard is 36mg/kg. The high value of Cu in the soil was much higher in site S5, S6, S7 and S8 with 56.8, 48.6, 47.2 and 49.6mg/kg respectively.

Pb concentration in the soil samples from sampling sites also varied widely from 1.5-96.3 mg/kg. The FAO limit of Lead is 85 mg/kg, soil values of S5, S6, S7 and S8 were high and exceeded the recommended limit.

The concentration of chromium in the soil was found in the range from 0.1 to 1.4 mg/kg, permissible limit recommended by WHO standard is 100 mg/kg for chromium. All the soil samples were within the permissible limit.

Heavy metals concentration are in the order of Ni>Pb>Cu>Cr and shown in Figure 2.

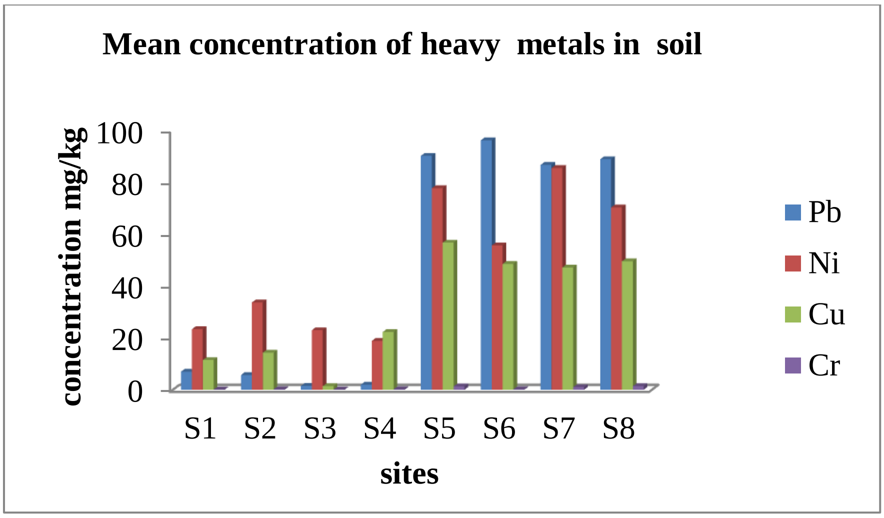

Figure 2. Mean concentration of heavy metals in soil at area

5.4 Heavy metal concentration in water

Heavy metals concentration (mg/l) of water sample investigated is shown in Table 3 and Figure 3. Most of the sampling points have elevated mean levels of mercury, nickel and lead which are above WHO guideline value.

Table 3. Mean concentration of heavy metals in water samples

water sample	Pb mg /l	Cr mg /l	Cu mg /l	Hg mg /l	Ni mg /l
w1	0.022	0.002	0.009	0.001	0.015
w2	0.042	0.001	0.010	0.002	0.018
w3	0.060	0.001	0.013	0.002	0.019
w4	0.214	0.004	0.011	0.002	0.018
w5	0.260	0.002	0.108	0.007	0.022
W6	0.690	0.002	0.119	0.021	0.022
W7	0.520	0.002	0.115	0.022	0.023
w8	0.800	0.002	0.123	0.046	0.024
WHO (2006)	0.05	0.05	0.05	0.002	0.02
NEQ (2015)	0.2	0.1	0.3	0.002	0.5

National Environmental Quality (Emission) Guidelines (2015)

Concentrations of chromium range between 0.001 and 0.004 mg/l which were below the World Health Organization (WHO) drinking water guideline values of 0.02mg/l of Cr.

The maximum permissible limit of WHO for Ni in water is 0.02mg/l. Concentration of Ni in water samples ranged from 0.015 to 0.024mg/L in which 50% of samples exceeded the WHO permissible limit .

Results indicate that concentrations of mercury in W5, W6, W7 and W8 were above the maximum limit for drinking water of 0.002mg/l.

Copper concentration in water samples of W1-W4 were within recommended limit for drinking water of 0.05 mg/l but others are above WHO standard limit

Concentration of lead in water sample ranged between 0.022-0.800mg/l. In almost all the collected water samples concentration of lead were recorded above the permissible WHO recommended guideline concentration of 0.05mg/l.

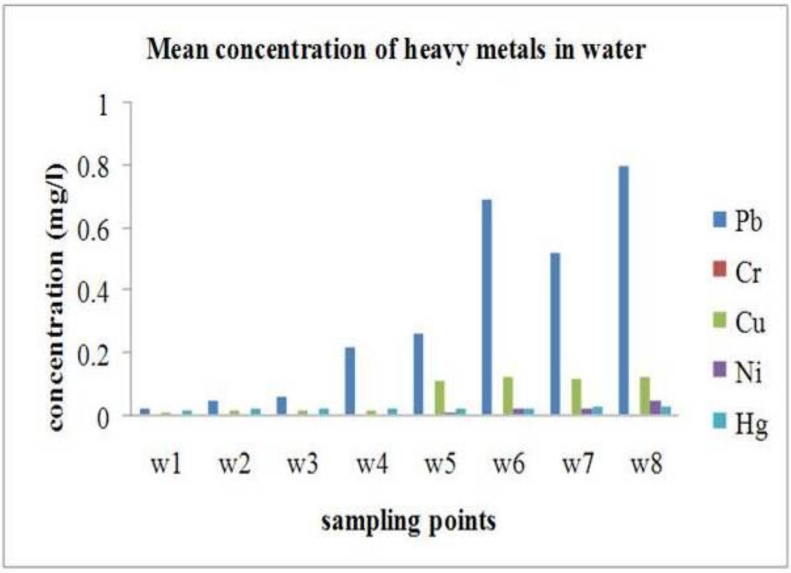

Figure 3. Mean concentration of heavy metals in water samples

6. Discussion

Artisanal mining generally involves non-regulated practice and a common approach to mineral exploitation in many developing countries (Mason, 2014) .In the study area, small scale mining of the gold resources has begun over 20 years ago but the importance of the mining activities appears unnoticed in the community based on the poor state of the infrastructure of the area.

Bordo and Flandreau (2003) noticed that resource bases such as communities in a mining site are generally degraded as a result of the ecosystem disruptions that are often occasioned by the unsustainable exploitation of its resources.

Active and abandoned mine sites have greater percentage of sandy soils than undisturbed or mine out areas. Although this study could not establish a cause-effect relationship between the mining activities and soil properties, the processes involved in the artisanal gold mining, which requires soil to be removed, sieved, or separated during gold search are capable to reduce its compaction and destroy the molecular bonds of the silicate minerals (Ge & Ma, 2007; Spiegel, Keane, Metcalf, & Veiga, 2014).In addition, the low organic matter content in the mining area in washing basin of abandoned sites reflects the scarcity of vegetation cover.

6.1 Heavy metal concentration in soil

The concentrations of the heavy metals are in the order of Ni>Pb>C > Cr in the study area as shown in Figure 4.

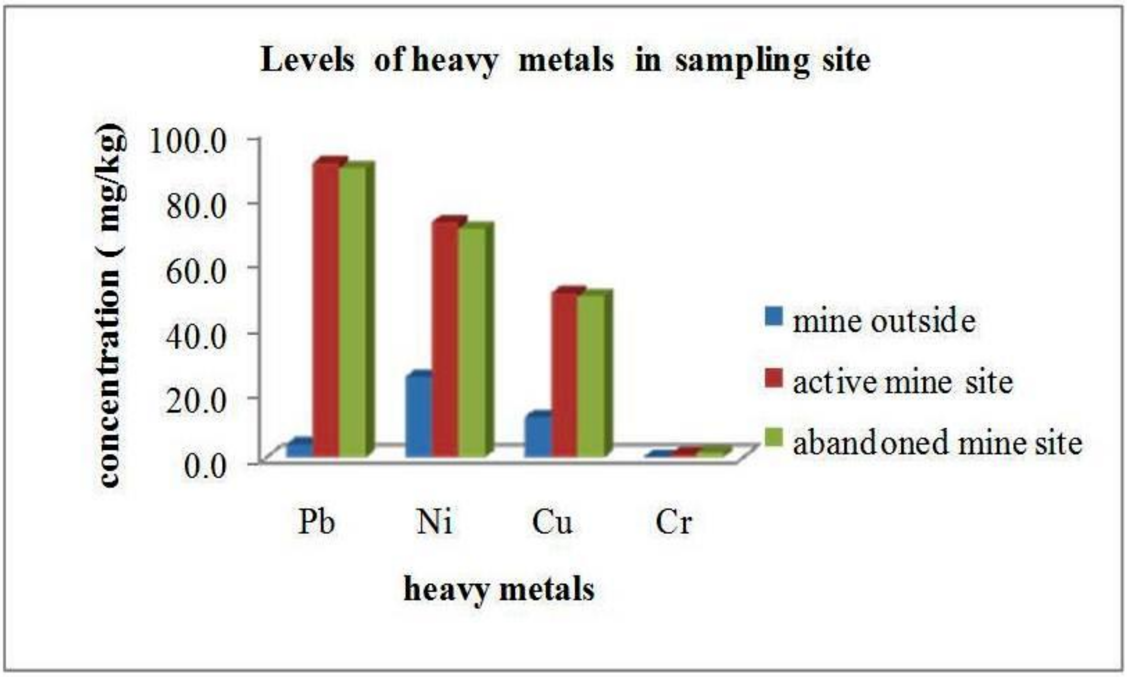

Figure 4. Levels of heavy metals in sampling sites

In general, the results of the heavy metals analyzed in control areas showed that their concentration level are below the standard guide lines for maximum limit proposed for agricultural soil. Even though these heavy metal concentrations fell below the critical permissible concentration level in most heavy metals, it seems that their persistence in the soils of the study site may lead to increased uptake of these heavy metals by plants.

Heavy metal concentration of Ni, Pb and Cu in both active and abandoned areas are recorded above the WHO permissible limit. The maximum concentration of heavy metal in S7 and S8 points might be due to the precipitation of heavy metal from rock dumps deposited adjacent mine shaft as well as discharging of mine drainage from mine shaft to the surrounding. The result of this study agrees with the observations of many studies that have previously been conducted around mine sites in different parts of the world (Jung 2008) similarly reported elevated concentrations of heavy metals in mine tailings and their vicinity.

6.2 Drinking and domestic water quality

The drinking and domestic water quality criteria for this study are based on world Health Organization (WHO) Guideline for drinking water.

In present investigation, pH and alkalinity of water samples are within the permissible limits set by WHO. The high turbidity content was found in some water sample points of W6 to W8. It was due to run offs and waste from the extraction of gold.

The concentrations of Cr, Cu, Hg and Ni in stream waters (w1-w4) are generally within the maximum permissible limit except Pb and presented in Table 4. Most of heavy metal concentrations in the waters of mind ponds and water inlets are above the WHO Guideline for drinking water and thus poses a quality problem. They are unfit for drinking, domestic and agricultural use. The possible health effects of these heavy metals in humans and animals are also presented in Table 2. These effects will get to human and animal systems via water intake/uptake.

Table 4. Evaluation of heavy metals in waters of the study area for drinking/domestic purposes and possible health effects

Heavy Metals	WHO (2006) guide line		Waters from the study area		
	Desirable Limit	Permissible	Range	Mean	Evaluation for drinking and/possible health effects
Cr (mg/L)	<0.05	<0.1	0.001-0.002	0.002	Excellence to good
Cu (mg/L)	<0.05	<1.0	0.009-0.123	0.064	High to good. May be carcinogenic; May cause kidney damage, convulsions, dermatitis anddiathasis
Pb (mg/L)	<0.01	<0.05	0.022-2.40	0.540	Very high. May cause neurological impairment and central nervous systemmal functioning.
Ni (mg/L)		<0.02	0.015-0.024	0.020	High to good. May be carcinogenic; May cause allergies and skin problem.
Hg(mg/L)		<0.002	0.001-0.046	0.013	Very high. May be kidney damage, tremor, restlessness, anxiety, depression and sleep disturbance

6.3 Assessment of metal contamination

Geo accumulation Index (Igeo) as introduced by Muller (1969) has been extensively used to assess the degree of metal contamination in terrestrial aquatic and marine environments. Muller proposed seven descriptive classes of geo accumulation index, which was used to estimate the heavy metal contamination and presented in Table 5.

Table 5. Muller' classification for Geo accumulation Index (Igeo) scale

Class	**I geo Value**	Quality
0	0	Uncontaminated
1	0-1	Uncontaminated to moderately contaminated
2	1-2	Moderately contaminated
3	2-3	Moderately to heavily contaminated
4	3-4	Heavily contaminated
5	4-5	Heavily to extremely contaminated
6	> 5	Extremely contaminated

Heavy metal pollution index values in soil indicated that (S1-S4) of mine outside area and natural forest or undisturbed area were unpolluted as shown in Table 6 and Figure 5.

Table 6 . Igeo index values in soil of study sites

Site	Pb	Cr	Cu	Ni
S1	0.279	0.002	0.761	0.244
S2	0.347	0.003	1.095	0.199
S3	0.034	0.002	0.748	0.052
S4	0.540	0.003	0.614	0.070
S5	1.178	0.003	1.811	3.362
S6	1.144	0.016	2.782	3.030
S7	1.376	0.021	2.529	3.153
S8	1.202	0.022	2.288	3.107
Avg.	0.76	0.01	1.58	1.65

Igeo value of Pb in abandoned mine sites (S5-S8) have moderately polluted and strongly polluted by Ni have Igeo= 3-4, whereas Cu was unpolluted to moderately polluted. This suggested that agricultural productivity may decrease with soil contamination for the food security.

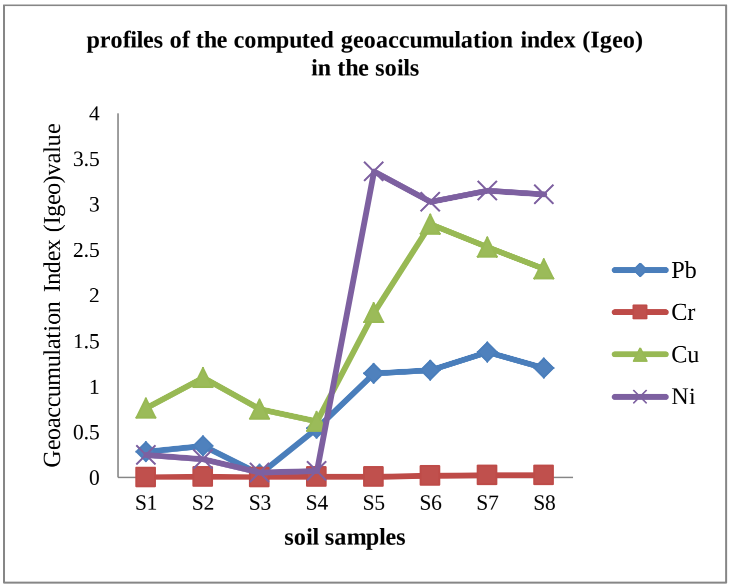

Figure 5. Profiles of computed geoaccumulation index (Igeo) in soils of study area

The computed values of the geo accumulation index (Igeo) of the heavy metals in the waters of the study area are presented in Table 7.

Table 7. Igeoindex values in waters of study area

Water sample	Pb	Cr	Cu	Ni	Hg
w1	2.29	-0.71	-0.01	5.02	0.37
w2	3.22	-0.71	0.04	5.28	0.37
w3	3.69	0.35	0.02	5.38	0.73
w4	3.58	0.35	0.01	5.38	0.37
w5	5.85	0.35	0.33	5.58	2.23
w6	7.26	0.35	0.36	5.61	3.82
w7	6.84	0.35	0.35	5.65	3.89
w8	7.44	1.38	0.37	5.71	4.95
Avg.	**5.27**	**0.21**	**0.34**	**5.45**	**2.09**

The calculated Igeo in table 7indicated that stream waters(w1-w4) are unpolluted with values for Cr , Cu and Hg metals , all having Igeo = 0-1 and moderately to heavily polluted by Pb (class 2-4) and Ni(class 6) .

I_{geo} value of Cr and Cu in water samples of mind ponds and water inlets in abandoned site (w5 - w8) were condition ranging from non-polluted to moderately polluted. Hg values are fluctuated between moderately and strongly/extremely polluted in these samples, whereas Pb and Ni show extremely polluted.

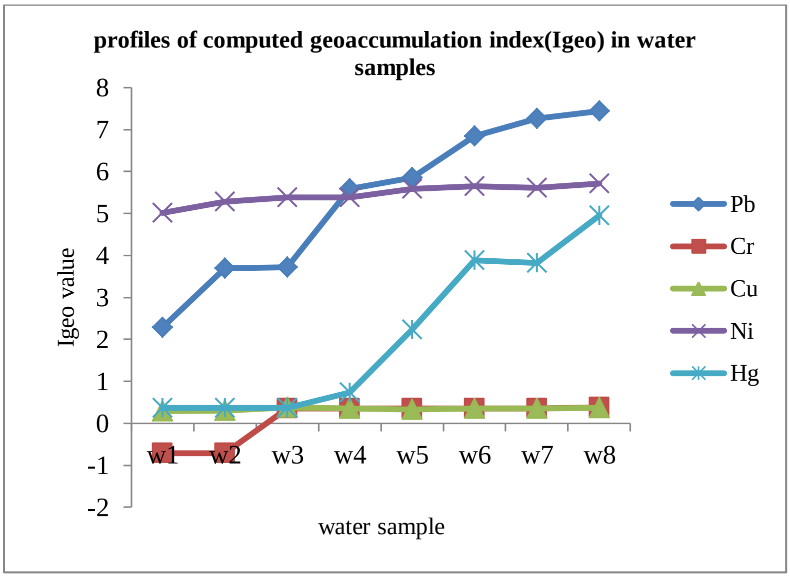

Figure 6. Profiles of computed geoaccumulation index (Igeo) in water samples

The relatively high Igeo values for Ni and Pb in the waters of the study area could be due to the mining and mineral processing activities as well as weathering of natural mineral deposits in the area.

7. Conclusion and Recommendations

The findings in this study showed that heavy metals concentrations of soil in mine-outside or undisturbed areas are within WHO limits and metal pollution index values are unpolluted. Active and Abandoned mine sites have high risk of accumulating heavy metal beyond their permissible limits especially for Pb and Ni, and Igeo value of these metals are moderately to strongly polluted. It is concluded that agricultural productivity may decrease in soil contamination for food security.

In this study, heavy metal concentrations in surface stream water are within WHO recommended limit for drinking water , except Pb. Concentration of Hg, Pb, Cu and Ni in mind ponds and water inlets are above WHO limits. Average (Igeo) value of Ni and Pb in most of the waters in the study area are extremely contaminated. It should be noted that minimum threats to public health and agricultural purpose for the entire community in the vicinity of mining area.

Mitigating Measure of Water Contamination shall be reduced by do not amalgamate in a river or pond that is used for drinking, cooking, washing or growing fish. Small amounts of mercury are always lost during amalgamation and can be transformed to the much more toxic methylmercury form which accumulates in fish. Amalgamate in a pond dedicated for this purpose. Locate the pond well away from a river or lake to prevent small amounts of mercury from being washed into the river or lake during the rainy season. Certain fish species naturally have higher mercury than other fish species. Avoid consuming fish that eat other fish (i.e., carnivorous fish) and instead select fish that prey on insects or plants (e.g., carp, tilapia, minnows, some catfish).

The study suggests immediate remediation strategies should be done in abandoned mining areas. The current study only provides preliminary information on heavy metal levels in soil and water from abandoned mining areas, further detail studies are needed.

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Appendix I

Physical and chemical properties of soil in study Area

Particular	Depth cm	pH	Total N %	Ava. P %	Ava. K %	OM %	Particle size distribution (%)			Remarks
							sand %	Silt %	Clay %	
S1	0-15	7.3	0.067	0.00046	0.0060	5.42	68	18	11	Sandy loam
S2	0-15	7.3	0.080	0.00026	0.0070	4.20	66	20	10	Sandy loam
S3	0-15	7.6	0.075	0.00024	0.0058	2.39	68	19	14	Sandy loam
S4	0-15	7.4	0.052	0.00019	0.0075	1.44	58	22	12	Sandy loam
S5	0-15	6.1	0.043	0.00003	0.0067	0.67	77	13	8	Loamy sand
S6	0-15	5.9	0.071	0.00072	0.0064	0.76	72	18	8	Loamy sand
S7	0-15	5.8	0.044	0.00007	0.0065	0.55	83	7	4	Sand
S8	0-15	6.2	0.052	0.00007	0.0066	0.17	81	9	5	Sand

Physical and chemical properties of water in study Area

Particular	Depth cm	pH	Alkalinity mg/L	Turbidity (FNU)
W1	0-15	7.97	71.0	3.34
W2	0-15	8.02	89.0	5.68
W3	0-15	7.06	63.0	7.73
W4	0-15	8.01	64.0	16.59
W5	0-15	7.94	68.5	109.20
W6	0-15	7.79	77.5	1063.60
W7	0-15	7.97	65.5	148.97
W8	0-15	8.05	74.5	159.90

Appendix II

Analysis of Variance for Heavy metals concentrations in soil

		Sum of Squares	df	Mean Square	F	Sig.
concentration	Between Groups	45565.457	7	6509.351	9.448	.000
	Within Groups	60626.195	88	688.934		
	Total	106191.653	95			
metal	Between Groups	.000	7	.000	.000	1.000
	Within Groups	120.000	88	1.364		

One-Sample Test for Heavy metals concentrations in abandoned and mine out site.

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
concentration	9.181	23	.000	48.591667	37.64273	59.54060