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Assessment of Soil Pollution (Heavy Metal) from Small Scale Gold Mining Activities: A Case of Nyarugusu Gold Mines, Geita – Tanzania

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Abstract

This research study investigated the concentrations of some heavy metals (Hg, Pb, Cu and Zn) in soil samples collected from Nyarugusu Gold Mines (located in Geita Region, Tanzania) using Atomic Absorption Spectroscopy (AAS). The results obtained showed that average concentration for Hg (25.45 mg/kg) was higher than the tolerable limits recommended by the United States Environmental Protection Agency (US-EPA). The average concentrations for Pb (10.14 mg/kg), Cu (19.75 mg/kg) and Zn (17.34 mg/kg) were found to be lower that tolerable limits, as prescribed by US-EPA. The high concentration of Hg measured at Nyarugusu site indicated existence of high health risks to plants animals and (especially humans). pH values for the soil samples were between 6.0 and 6.92 which is also dangerous for the availability of metallic minerals for plants consumption.

Keywords

Heavy Metals, Soil, Atomic Absorption Spectroscopy, Small Scale Mining

1. Introduction

Tanzania is one of the countries in Africa that are highly endowed with mineral resources and is ranked fourth after South Africa, Democratic Republic of Congo and Ghana [1-3]. Minerals available in Tanzania can be categorized into four main groups: metals, energy, industrial and gemstones [1], [4]. Most of these minerals are formed near surface, hence favorable for small scale mining (SSM) [2]. It is anticipated that almost 60% of small scale miners in Tanzania are involved in Gold mining [1]. The United Nations Economic Commission for Africa [5] and [1] pointed out specific areas where small scale miners are found in Tanzania, including Sambaru and Londoni (Singida), Nyarugusu, Mgusu and Rwamgasa (Geita), Mererani (Manyara), Kalalani and Kigwase (Korogwe), Buhemba (Musoma) and Ngapa (Tunduru). It is estimated that there are about 650,000 to 750,000 small scale miners in the country, out of whom 80% are believed to be working in the Lake Victoria Gold Fields (in which the Nyarugusu Gold mines are found [1]. Realizing the contribution of small scale miners in the country's economy, the Government of Tanzania through the Ministry of Energy and Minerals demarcated areas for SSM activities. These include Ngembambili (Kitai), Masuguru and Makoro (Mbinga), Mpwapwa (Dodoma), Ngasamo, Rwamgasa and Nyarugusu (Geita), Winza (Bukombe), Mererani (Manyara), Makanya (Same), Rwabasi (Musoma) Sezakofi and Mumbwi (Handeni), Nyasanero (Musoma) and Ilagala (Kigoma vijijini) [2].

Generally, SSM is an informal and highly disorganized mining endeavor which is characterized by a relatively low degree of mechanization, high degree of labor intensity, poor occupational and environmental health standards, little capital investments and lack of long term planning (Figure 1) [2], [6-7]. Nevertheless, SSM provides 13 to 20 million jobs worldwide, with 80 to 100 million people depending on it for their livelihoods [2], [8-9].

***Figure 1.** SSM activities at Nyarugusu Gold Mines.*

Small scale gold mining activities can cause negative impacts on both society and the environment [1], [3], [8-9]. The nature and type of the impacts depend on the type of the mineral being mined, the mining and mineral processing methods in use and the mining phase [3]. Uncontrolled mining operations can be a source of heavy metal pollution to soils, water, sediments and air through various mechanisms such as deforestation, soil erosion, river siltation, landscape destruction, amalgam burning and waste/tailings disposal, as depicted in Figure 2 [9]. Also, these mining activities are associated with health hazards, including exposure to toxic dust, chemicals, noise and vibrations [3]. The existence of poor working environment such as poor ventilation, extreme heat and humidity, accidents from rock falls, explosions and floods and the outbreak of communicable diseases (i.e. HIV/AIDS) are also the major challenges [1].

Heavy metal pollution is felt in many parts of the world, especially developing countries like Tanzania [10-12]. According to [10], the release of heavy metals from mining areas mainly occurs through acid mine drainage and erosion of waste dumps and tailings deposits. Heavy metal pollution may lead to serious disruption of biological and biochemical processes in a human body, which may lead to different disabilities such as mental retardation and loss of sight [9]. Infact, the contaminations of aquatic and terrestrial ecosystems with heavy metals have been a major environmental problems in almost all SSM areas of the world including Tanzania [13-15].

Some common heavy metals associated with SSM include Mercury, Nickel, Lead, Cadmium, Copper, Aluminum, Platinum and Arsenic (metalloid) [11-12], [16]. It is known that some of these metals are very toxic not only to humans, but also to the whole environment in its totality. For instance Mercury causes many harmful effects in humans' nervous system [14], [17-18]. Also, according to the United States Environmental Protection Agency [19], Lead is the most common heavy metal contaminant in the environment and may be toxic to organisms even when absorbed in small amounts. Cadmium is a heavy metal of major environmental concern because of its high mobility and the small concentration at which it can adversely affect plants and animal metabolism [20]. Considering such hazardous nature of these aforementioned heavy metals, it is therefore the aim of this research work to assess environmental effects caused by heavy metal pollution from SSM activities at Nyarugusu Gold Mines, Geita – Tanzania.

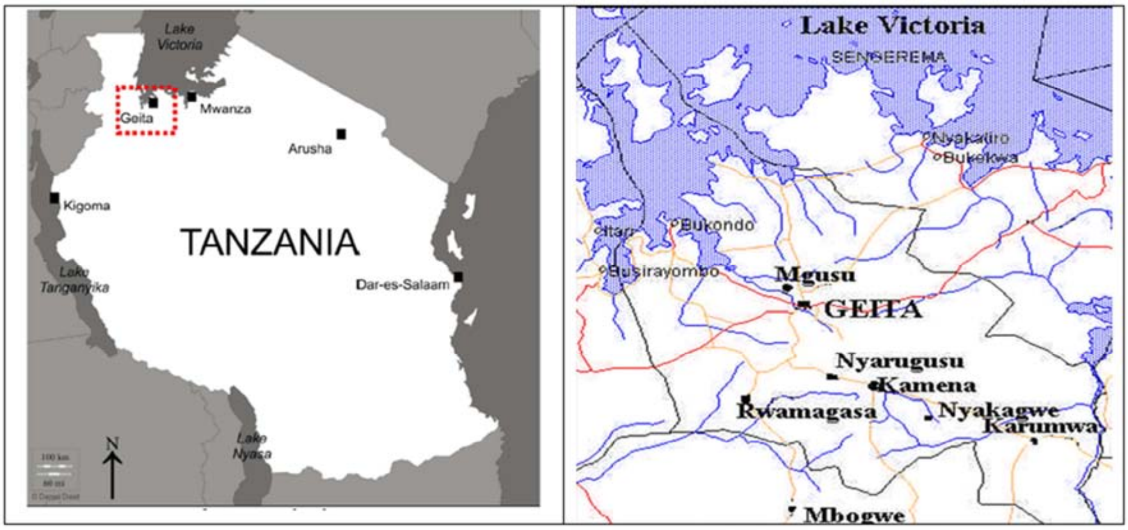
Source: [2]

***Figure 2.** Typical low degree of mechanization and poor occupational and environmental health standards.*

2. Materials and Methods

2.1. Description of the Study Area

This study was conducted in Nyarugusu, one of the main small scale mining centers located in Geita Region (Figure 3). Geita is located in the Lake Victoria Goldfields (LVG) which is defined as the area surrounding Lake Victoria which is active in Gold mining activities. Gold mineralization in the LVG is of four types namely; auriferous quartz reefs and stringers, auriferous sulphide impregnation consisting of large scale disseminated sulphide replacements of banded iron formations (BIF), alluvial gold deposits in laterites and alluvial or stream sediment placer deposits [21-23].



Source; [21], [23]

Figure 3. *Location Map of Geita District showing major small scale Gold mining centers.*

2.2. Sample Collection, Preparation and Analysis

2.2.1. Sample Collection

In this study, eight (8) surface soils samples were collected from four (4) specific areas in which Gold processing activities were concentrated. The samples were collected from the sample location using clean stainless steel material and were collected at 15cm depth around the sample area; it was thoroughly mixed and transferred into clean and labeled polythene bag for onward analysis in the laboratory [24].

2.2.2. Sample Treatment

The soil samples were oven dried at 105°C to constant weight for 6 hours [25]. The oven dried material were crushed and sieved through 2.00mm mesh to obtain representative samples [24].

Soil pH

Soil pH was determined in 1:1 soil water suspension and 1:2 soil 0.01M calcium chloride suspension as described in [26]. 20g of air dried soil sample was weighed into a 50cm^3 beaker and mixed with 200 cm^3 of distilled water and 0.01M $CaCl_2$ separately. The mixture for each was stirred for 30 minutes and allowed to stand for 1 hour. The pH reading was taken after inserting the electrode of the pH meter into the partly settled suspension and reported the result as soil pH in water and 0.01M $CaCl_2$. The pH meter was calibrated with 7.0 distilled water and pH buffer solution before used. The electrode was washed and wiped with dry clean filter paper after each reading [25].

2.2.3. Sample Digestion

1g of the oven dried ground sample was weighed using a top loading balance and placed in a 250 ml beaker which has been previously washed with nitric acid and distilled water. The sample was reacted with 5 ml of HNO_3, 15 ml of concentrated H_2SO_4 and 0.3 ml of $HClO_4$ using dropping pipette. The mixture was digested in a fume cupboard, heating continued until a dense white fume appeared which was then ingested for 15 minutes, set aside to cool and diluted with distilled water. The mixture was filtered through acid washed Whattman No.44 filter paper into a 50 ml volumetric flask and diluted to mark volume [27-29]. The sample solution was then aspirated into the Atomic AAS machine at intervals for the determination of heavy metal contents for; Hg (its presence was due to the use of Hg during amalgamation), and Pb, Zn and Cu (whose presence is associated with Gold ores).

3. Results and Discussion

3.1. Heavy Metal Concentrations in Soil

Results from this study (average concentrations of heavy metals in soil) are as described in Table 1. The mean concentration of Hg was found to be 25.45 mg/kg, which is far higher than the maximum allowed concentration of 1 mg/kg, recommended by US-EPA [17-18]. The maximum measured Hg concentration was 78 mg/kg, which is also very much higher than the maximum allowed Hg concentration in soil. This scenario was highly contributed by high application of Hg during amalgamation processes for Gold recovery from mineral processing activities by artisanal and small scale miners at Nyarugusu site.

Furthermore, Pb was found at an average concentration of 10.14 mg/kg, which is below the maximum allowed Pb concentration of 200 mg/kg, recommended by US-EPA [17-18]. The maximum measured Pb concentration was 18.5 mg/kg, which is also lower than the maximum allowed Pb concentration in soil. The mean concentration for Cu (19.75 mg/kg) and Zn (17.34 mg/kg) were lower than the allowable limits of 270 mg/kg and 1100 mg/kg respectively, recommended by US-EPA [17-18]. This signifies that there are no existing health hazards related to Pb, Cu and Zn pollution at Nyarugusu Gold mining site.

Table 1. *Measured concentrations versus standard limits of heavy metal concentrations in soil.*

Heavy metals conc. (mg/kg)	Observed mg/kg		Standard Limits (mg/kg)[1]
	Range	**Mean**	**Mean**
Hg	0.01-78	25.45	1
Pb	0.01-18.5	10.14	200
Cu	0.1-72	19.75	270
Zn	0.001-23.5	17.34	1,100

Higher concentration of Hg (25.45 mg/kg) measured at Nyarugusu SSM signifies that soils at Nyarugusu Mines possess a significant health threat to the indigenous environment. Accumulation of heavy metals in soils leads to increased bio-concentration and bio-accumulation in plants, livestock and humans, mostly through the food chain [30]. Bio-concentration and bio-accumulation of heavy metals in plants and livestock possess an indirect health risk to humans, as they are at the end of the food chain. Consumption of food and water polluted by heavy metals has been connected to many health problems that endanger human life, including wide range of carcinogenic pathogens (skin, liver and kidneys), teratogenic effects, mutagenic effects as well as brain damage [9], [17-18], [31]. Current world trends indicate that there is a very high pollution of the environment components by heavy metals accrued from mining activities [4], [9-10], [31]. It is clearly anticipated that the risk level to plants and animals (including humans) life at Nyarugusu SSM will increase with time if immediate efforts will not be taken to rescue the situation for the well-being of the current and future generations.

The concentration of heavy metals in the soil in the study area may be due to the area been used for many years for extraction of precious metals. The concentration of mercury in soil and tailings indicates the significant amount of mercury is left in tailings during amalgamation which through the percolating water cause contamination of surface and ground waters.

1 [17-18]

3.2. Soil pH

Table 2 gives a clear picture of variations of pH across various soil samples collected around Nyarugusu small scale mining site.

Table 2. *pH measurements for various soil sampling point.*

Points	1	2	3	4	5	6	7	8
pH	6.91	6.92	6.91	6.48	6.55	6.3	6.38	6.0

Results in Table 2 indicate that pH in soils varied from 6.0 - 6.92. The recommended standards pH in soils [17-18] is between 6.3 and 8.5, indicating that 50% of the pH values observed in the study were beyond (outside) the recommended range. This is mainly due to Acid Mine Drainage; a condition that occurs when sulphide ores (Gold bearing ores) are exposed to the atmosphere (oxygen and water) to form typical acids (mainly Sulphuric acid) that are dangerous to the natural environment. These acids may then react with heavy metals in soil and cause deficiency of plant nutrients (i.e. K, Ca and Fe) which in turn results into poor soil fertility in the respective agricultural areas [24], [32].

4. Conclusion and Recommendations

This study indicates that 25% of the heavy metals investigated were found to be higher than the tolerable limits for safe environment as prescribed by United States Environmental Protection Agency (US-EPA). These high concentrations of heavy metals observed in soils at Nyarugusu Gold Mines implicate high health risks to animals (especially humans) and plants. This research study suggests that immediate and serious measures be undertaken by relevant organs (Ministry of Energy and Minerals, National Environmental Management Council and the Division of Environment – Vice President's Office) to reduce the anticipated health impacts to the surrounding communities.

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