EFFECTIVENESS OF POST-MINING REHABILITATION ACTIVITIES AT RESTORING MACRO AND MICRO NUTRIENTS TO DEGRADED MINE SITES IN THE WESTERN REGION OF GHANA

Adonadaga, M-G.
Department of Environmental Science, School of Environment and Life Sciences
C.K Tedam University of Technology and Applied Sciences, Navrongo, Ghana

Sambil-Kolog, S.
Department of Environmental Science, Faculty of Earth and Environment,
University for Development Studies, Tamale, Ghana

Ampadu, B.
Department of Environmental Science, School of Environment and Life Sciences
C.K Tedam University of Technology and Applied Sciences, Navrongo, Ghana

ABSTRACT: *The clearing of large tracks of land for surface mining has serious effects on vegetation, soil and the ecosystem as a whole. As a result, such lands need to undergo post-mining rehabilitation in order to restore their value and productivity. The aim of this study was to assess the effectiveness of reclamation activities at some degraded mine sites located in the Damang area of the western region of Ghana, based on soil nutrients availability. Levels of macro and micro nutrients in five reclaimed sites and one undisturbed site, used as control, were determined using Atomic Absorption Spectrophotometry. For the macro nutrients, the control site recorded the highest values of 0.27% and 8mg/kg for Nitrogen and Phosphorus respectively while the lowest values of 0.04 % and 1.2mg/kg were recorded at RS2 and RS1 respectively. Also, the highest value for Iron, 33.3mg/kg, was recorded at CS with the lowest value of 3.1mg/kg recorded at RS1. All the values of the micro-nutrients were within the permissible levels set by the FAO. The results generally indicate that the reclamation exercise is achieving some degree of success. Regulatory agencies should undertake continuous monitoring of reclamation activities to ascertain their success or otherwise.*

KEYWORDS*:* surface mining, land degradation, rehabilitation, soil nutrients

INTRODUCTION

The rate of utilization of mineral resources is rapidly increasing with the advancement of science and technology, economic development, industrial expansion, acceleration of urbanization and population growth. The development of society and civilization is partly dependent upon the mining industry to operate and maintain environmental sustainability. For Ghana in particular, the mineral extraction industry has historically been of great importance to the country's economic development (Akabzaa, 2000; Agbesinyale, 2003), with the pre-independence name, Gold Coast, depicting the significance of the mining sector to the nation. Ghana is enriched with mineral deposits and was ranked tenth in the world and second in Africa on the list of World Gold producing countries for 2013 and 2014 (Gold Fields Minerals Services (GFMS) Gold Survey, 2015).

Surface mining is the method of mining that involves excavating to extract ores beneath the soil surface. It involves the clearing of vegetation cover, removal of top soil by earth movers, drilling, blasting, loading and hauling of ore to the processing plant with huge machines such as dragline excavators and bucket wheel elevators. These processes are cyclical with intrusion in the extraction (drilling, blasting and loading) and the haulage. In general, most surface mining operations rely on mobile drill rigs, hydraulic shovels, front end loaders, scrappers and haul trucks to extract the ore and transport them to the ore processing unit. Yirenkyire (2008) indicates that, surface mining in a large number of mining nations has been promoted in recent years because of the following factors; consideration of costs and safety as compared to underground mines, low grade ore requiring massive amounts of processing, place of ore bodies and competition for investors between gold-producing nations.

Mining disturbs the landscape's aesthetics and soil elements such as horizons, structures, microbes and nutrient cycles. These are essential to maintain a healthy ecosystem and therefore their disruption leads to the destruction of plants and soil profiles (Cudjoe, 2011). Mine waste can have many impacts, including soil erosion, air and water pollution, toxicity, geo-ambient disasters, biodiversity loss and eventually financial loss (Wong, 2003; Sheoran *et al*., 2008). Soil provides the basis for plant communities, which directly affects the composition and density of the soil's future balance. Restoring vegetation cover on overburden dumps can achieve stability goals, contamination control goals, visual enhancement and the elimination of human threats (Wong, 2003). Recent studies, for example, Tieguhong *et al*. (2009) and Mehta (2002) observed that, surface mining have impacts on the external environment with emphasis on air and water pollution, especially the accumulation of mercury, cyanide and arsenic, land degradation, wildlife and fishery habitats, associated health hazards and human displacement.

The Minerals and Mining Act 703 (Minerals Commission, 2006) and the Environmental Protection Agency Act 490 (EPA, 1999) of Ghana require mining companies to carry out viable post-mining closure that incorporates the provision of sustainable alternative livelihood to the local people. Healthy and well rehabilitated mined land could serve as recreational areas, grazing lands and for arable agricultural development by the local people in order to sustain their livelihoods (Ansah, 2016). It is mandatory to guarantee a return of the productivity of the soil impacted by the mineral extraction method. Concurrent post-mining recycling of the degraded land has become an essential component of the whole mining spectrum by increasing environmental concerns. It is important that attempts to maintain and restore land resources continue to be beneficially utilized. Reclamation is the method of returning the fertility of degraded areas and restoring some biotic function and fertility. The prolonged recovery of mine spoil needs stable nutrient cycles resulting from plant growth and microbial procedures (Singh *et al*., 2002, Lone *et al*., 2008; Kavamura and Esposito, 2010). The people in the local community expect their lands to be returned to its state before the mining companies began to help them in farming. Meeting this expectation, however, has become a major challenge to many mining companies in the country, despite efforts by some mining companies to reclaim the degraded lands (Ansah, 2016).

While optimum amounts of nutrients are required for production of wholesome food crops, several studies in Ghana have revealed wide variations in nutrient levels of reclaimed mined soils and high heavy metal availability in these soils and the bioaccumulation of heavy metals in crops harvested from reclaimed lands and farmlands in mining communities (Hayford *et al*.

2008, Antwi, 2009; Tetteh, 2010; Adu, 2012). Hence, the quality of reclaimed soils need to be frequently assessed for good ecological, physico-chemical, micro-biological and climatic environments (Frimpong *et al*., 2014) to ensure the production of wholesome food crops.

This research work seeks to assess the effectiveness of the reclamation activities at the degraded mine sites based on the available soil nutrients. The specific objectives were to: a) identify the type of plants used in the reclamation process, b) determine the levels of macronutrients and micronutrients in the reclaimed lands, and c) compare the nutrients levels in reclaimed lands with those of the undisturbed area.

MATERIALS AND METHODS

Study Area

The study was conducted at Damang Gold mine which is located in south-western Ghana near the southern end (Figure 1) of what is commonly referred to as the Tarkwa Basin.

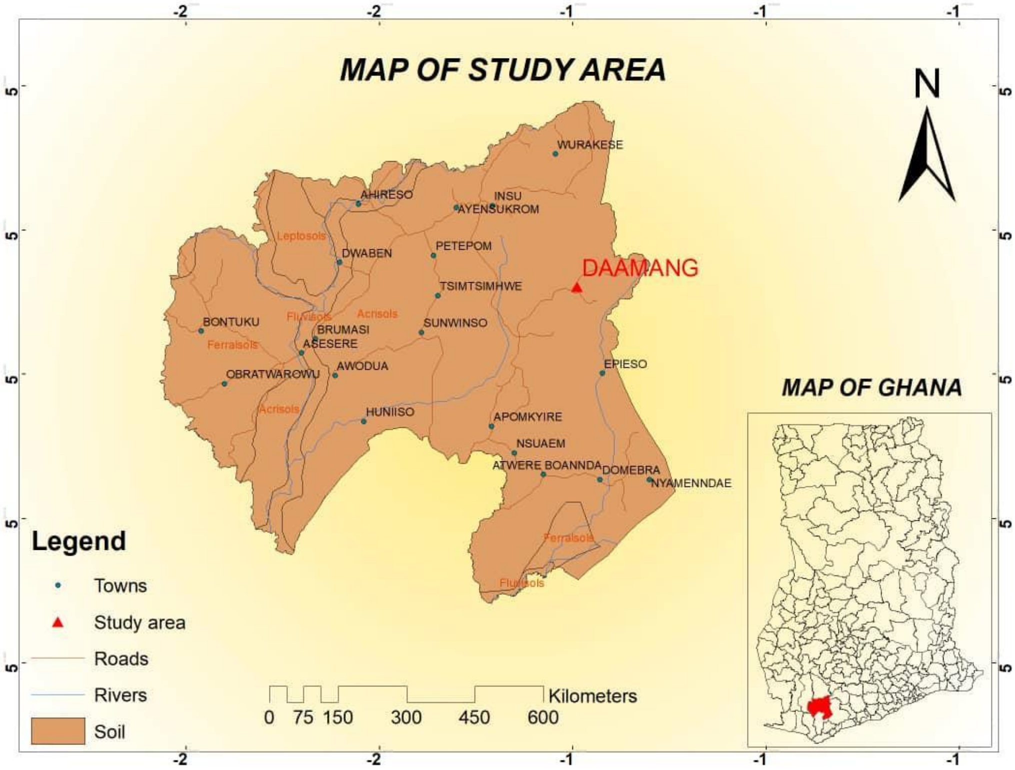

Figure 1: Map showing Ghana showing the location of study area

The Damang area falls within the wet, semi-equatorial climatic zone of Ghana. It is characterized by an annual double maxima rainfall pattern, occurring from March to July and from September to mid-November. The maximum local topographic relief is approximately 80m. Historically, this area has received an average annual rainfall of over 2,000 mm, but the

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records over the last 25 years show drier conditions, with an average of 1,800 mm per year at the project site, and temperature ranging between 24.5°C and 27.8°C, and an annual evaporation of 137 mm (AGL, EMP; 2017-2020). According to Ackah (2012) the major soil types identified in Damang are acrisol, fluvisol, luvisol and ferrosols.

Field Visits and Sampling

Visits were made to the various reclamation sites within the Damang mining area for observations on the types of plants and crops grown, and also to identify possible areas for soil samples to be taken.

Ten (10) reclaimed sites were identified in the study area out of which five were selected due to location and ease of accessibility. Study sites were selected such that each section of the reclamation area was represented. These sites were numbered as Research Site 1 (RS1) Research Site 2 (RS2) Research Site 3 (RS3) Research Site 4 (RS4) and Research Site 5 (RS5). The land use criteria and post monitoring of these sites have been completed and are actively utilized for agricultural production. In addition to the five, an un-disturbed land within the mining lease concession was selected as a control site (CS).

Figure 2: Picture of reclaimed site RS1

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Fig 3: Picture of reclaimed site RS2

Soil Sampling and Handling

For the purpose of ensuring that soil samples were representative of the reclamation sites, each site was divided into five subplots and a sample taken from each subplot. In all thirty (30) soil samples were extracted at a depth of 0-30 cm using a spud bar, hand trowel and/or spade. Each soil sample picked was placed in a well labelled transparent polybag, shaken to ensure uniformity and stored carefully to avoid microbial contamination. All the samples were collected during the dry season.

Sample Preparation and Laboratory Analysis

Samples were prepared for laboratory analysis by first transferring them into plastic trays for air drying so as to remove moisture from the samples and to avoid contamination during preservation. Samples were air dried for about 24 hours. In the process of air drying, large clods were broken down into smaller pieces to speed up the drying process. Samples were then ground mechanically, homogenized and sieved through a 2 mm pore sieve to remove debris such as roots, leaves and large stones. Clods which weren't able to pass through the sieve were crushed and sieved again. The prepared samples were stored in a clean small box or bottle.

Digestion is highly recommended to decompose a sample for nutrients analysis. An aqua regia solution of HCl and HNO_3 with amounts of 6ml and 2ml respectively was added to each sample and stirred for a while (Martin et al, 2003). Samples were then transferred into a heat resistant pyro beaker and the hot plate digestion method applied. Digestion was done according to the protocols at a temperature of 120^oC for a period of 45 minutes after which the extract was left to cool. It was then filtered and diluted with distilled water in a volumetric flask up to 50ml. Good mixing method was achieved by sealing and inverting the extract thoroughly.

The extracts from the samples were analysed for the following macro nutrients: Nitrogen (N), Phosphorus (P) and Potassium (K) and micro nutrients: Iron (Fe), Manganese (Mn) and Copper (Cu) using the AAS (Thermo Scientific Ice 3000 Series) based on standard methods.

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RESULTS AND DISCUSSION

Table 1 shows the mean concentrations of the nutrients obtained from the various study plots, and the control site.

Table 1: Mean concentrations of macro and micro nutrients for all study sites

Soil Nutrients	RS1	RS2	RS3	RS4	RS5	CS
N (%)	0.059	0.044	0.044	0.086	0.053	0.279
P (mg/kg)	1.2	2.2	2.2	3.8	4.4	8
K (mg/kg)	41.6	42.4	45.4	39.2	57	53.6
Mn (mg/kg)	40.6	51	42	37.4	36.6	39.74
Fe (mg/kg)	3.14	6.52	4.5	3.86	6.06	33.36
Cu (mg/kg)	39.2	47.2	47.6	40.2	43.2	29.2

Nitrogen

Mean concentrations of nitrogen ranged from a low of 0.044% at RS2 to a high of 0.086% at RS4 with the control site having the highest concentration of 0.27% (Table 1 and Figure 4). Nitrogen values for all the reclaimed sites, together with the control site are in range with the works of Adu (2012) who reported that the surface mineral soil's nitrogen content is usually between 0.02 and 0.5%. The level of nitrogen from the sites demonstrates a higher amount of nitrogen at control compared to the reclaimed sites. This could be attributed to leaf litter fall, higher decomposition and higher incidence of free, chemo-heterotrophic bacteria which promotes decomposition as indicated by Adu (2016).

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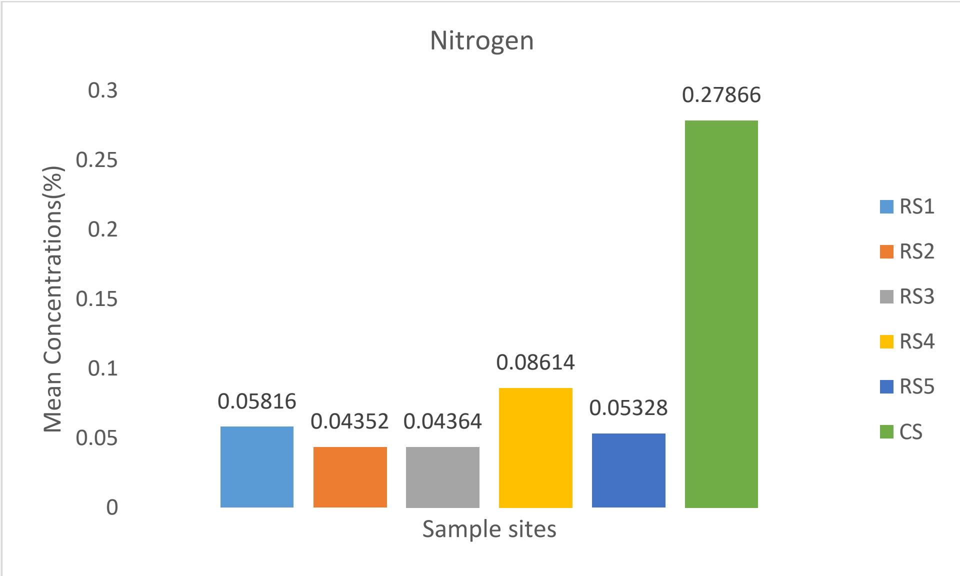

Figure 4: Concentrations of Nitrogen at various sites

The wide difference between the control and the reclaimed sites could be attributed to the quantity of top soil used in reclaiming, the deterioration of soil nutrients during the top soil storage period and the use of cover crops. The planting of suitable cover crops with nitrogen fixing ability helps put the soil into its natural state, with perennial plants producing abundant biomass preferable to annual plants (FAO, 2011). As stated by Diver *et al*. (2008), reclaimed sites need to have better nitrogen status, so interventions that help promote soil and plant health should be key to plant growth a way of achieving this is by planting leguminous cover crops that have the capacity to serve as pioneering herbaceous species. This will also serves as a soil cover to prevent soil erosion (Sangakkara *et al*., 2008). The effect of topsoil movement on nutrients has been reported by Schmidt (2002) and Mahood (2003). They reported that any relocation or storage of topsoil decreases nutrient levels, a possible reason for the low nitrogen levels in the reclaimed sites. The movement of topsoil from one place to another reduces its natural conditions such as moisture, soil aeration and salt content therefore, perhaps the causes of a reduction in nitrogen in the reclaimed sites as compared to the control site.

Phosphorus

Phosphorus recorded values between 1.2 and 4.4 mg/kg at RS1 and RS5 respectively, with the highest value of 8 mg/kg recorded at the control site (Table 1 and Figure 5), just like the case of nitrogen. This has some relation to the works of Brady and Weil (1999), which states that an undisturbed natural eco-system loses little of this nutrient because phosphorus does not form gasses that can escape to the atmosphere or leak with drainage water out of the soil.

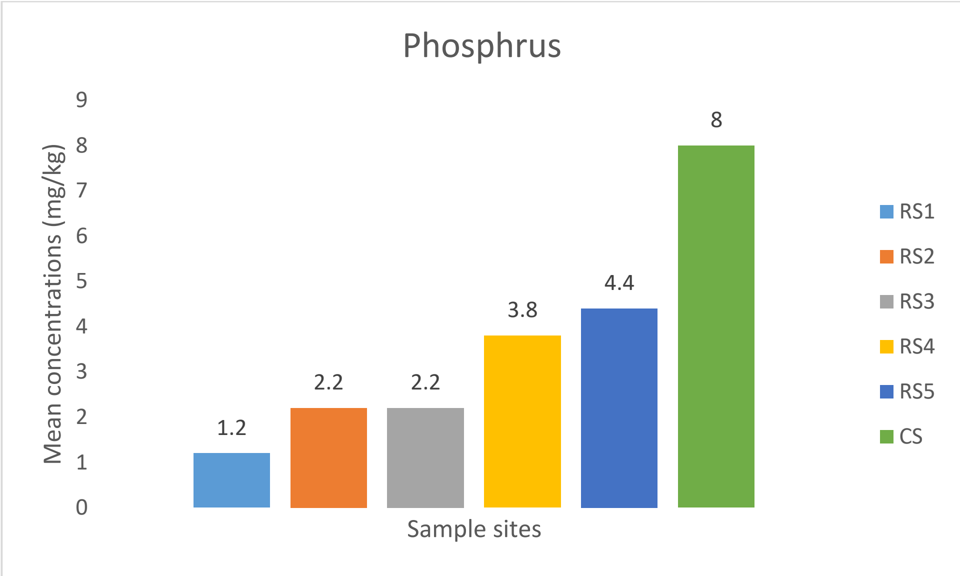

Figure 5: Concentrations of Phosphorus at various sites

The lower levels of phosphorus at RS1 can be as a result of deterioration of stockpiling topsoil as indicated above for nitrogen. Site conditions such as soil moisture, aeration and salinity may affect the levels of phosphorus.

Potassium

For potassium, the lowest value of 39.2 mg/kg was recorded at RS 4 and the highest of 57.0 mg/kg recorded at RS5 with the control site having a value of 53.6 mg/kg (Table 1 and Figure 6). Available potassium in these study sites were probably due to a greater percentage of the rocks in the site being unweathered.

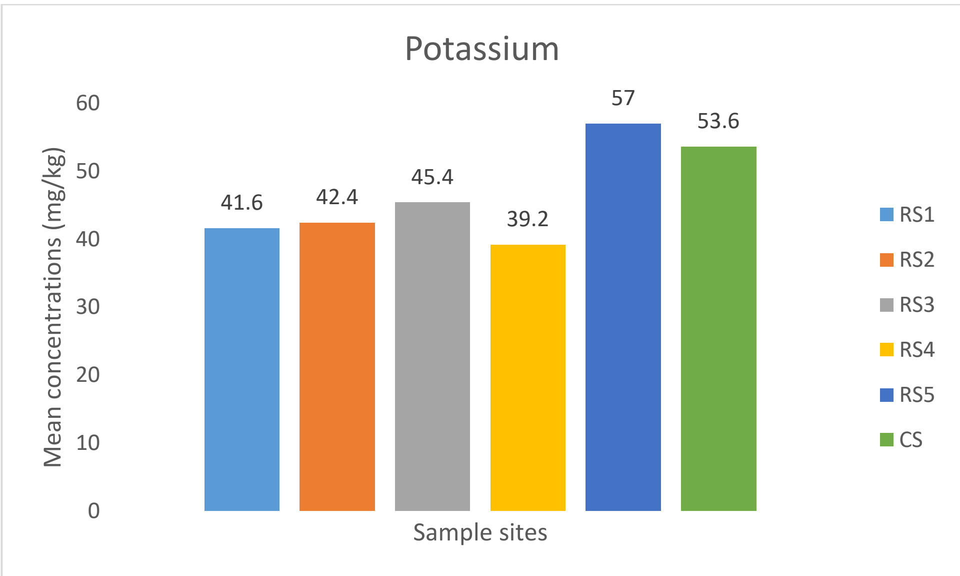

Figure 6: Concentrations of Potassium at the various sites

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The reclaimed sites and undisturbed sites registered appreciable concentrations of potassium that could probably be due to leaching which usually occurs in established tree stands and in the secondary forest (Young, 1997). The fluctuating concentrations of potassium across the reclaimed site together with the control site can be attributed to the pH levels of the various sites as asserted by Ansah (2016) that high pH influences potassium concentrations.

Manganese

Mn on the other hand, recorded a low of 36.6 mg/kg at RS5 and a high of 51 mg/kg at RS2 with the control site having a value of 39.7 mg/kg (Table 1). However, these values were in range with the recommended maximum permissible level of 1800 mg/kg set by the FAO (2011). Organic matter, pH, and weather conditions tend to influence soil manganese. At lower pH (< 5.5), for example, oxides of manganese can easily be reduced in soil exchange sites (Kogelmann and Sharpe, 2006), but the dominant soluble manganese may be leached in soils with good drainage as with the later reclaimed sites. High pH and organic matter allows manganese adsorption into soil complexing sites, thereby increasing their availability. Therefore, it could be concluded that soil within these sites are suitable for plant growth.

Iron

Similarly, Fe values ranged from 3.1 to 6.5 mg/kg with the lowest recorded at RS1 and the highest at RS2 whilst the control site recorded a value of 33.36 mg/kg (Table 1 and Figure 7). All these values are in range with the permissible limits of 5000mg/kg (FAO. 2011). The reclaimed areas have very low iron concentrations as compared to the undisturbed areas. According to Brady and Weil (1999), the general iron nutrient requirement of plants shouldn't be above 100 mg/ kg. By this affirmation, it can be assumed that all the study areas would have sufficient concentrations of iron available for use by plants that would be cultivated on them. The elevated iron concentration of the control site could be attributed to composition of the parent rocks since the undisturbed site has its original parent rock but the reclaimed sites have been altered and so therefore do not possess the parent rock.

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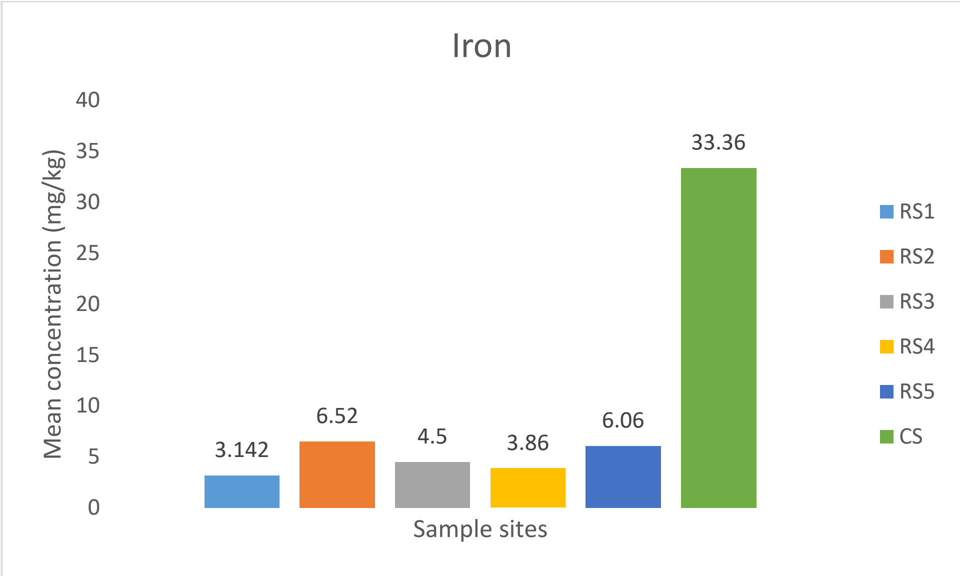

Figure 7: Concentrations of Iron at the various sites

In the process of extraction of ore, precisely drill and blast, the parent rocks of the disturbed sites are being drilled and blasted in order to get the ore. In the process of reclamation, the base of the soil used are not the original parent rocks but are waste rocks carried from different sites, making it impossible for it to carry its parent rock and therefore contributing to the lower levels of Fe in the disturbed areas. Also soil found in the locality is identified to be ferrosols (Ackah, 2012).

Copper

Values of 39.2 and 47.6 mg/kg were also recorded for Cu at RS1 and RS3 respectively, with the control site having a value of 29.18 mg/kg (Table 1 and Figure 8). However, these values are in range with the FAO permissible limits of 200mg/kg. With the copper level for all the study sites ranging from 29.18mg/kg to 47.6mg/kg, the area could be said to have sufficient levels of copper for utilization by crops. This is based on the statement made by Adu (2012) that the general nutrient requirement of plants with respect to copper is about 6.0 mg/kg. The elevated level of copper in the reclaimed areas than the control site could be attributed to the mining operation in the area and conforms to a study conducted by Boamponsem *et al*. (2010) about heavy metal concentration in the mining areas of Tarkwa.

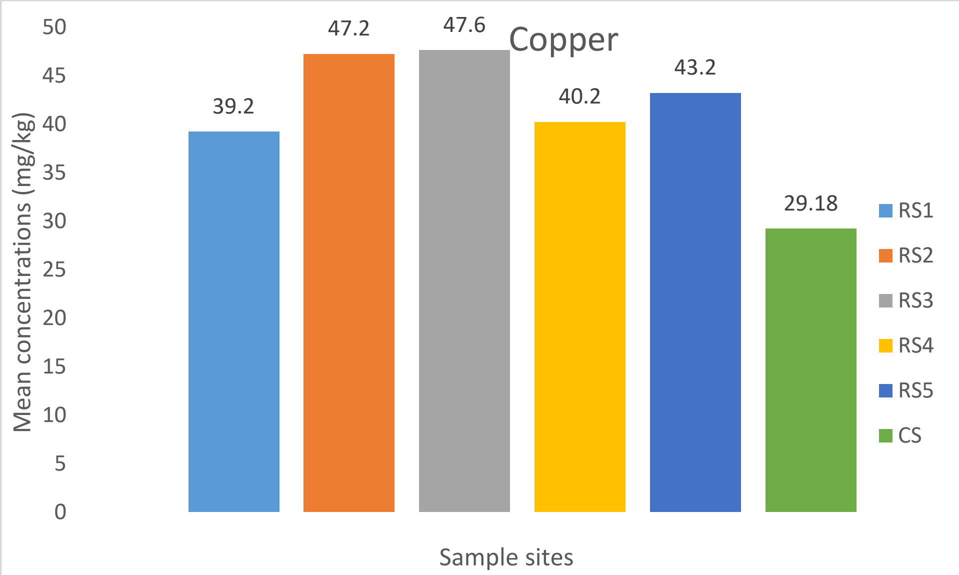

Figure 8: Concentrations of Copper at the various sites

The continuous accumulation of copper over a period has also contributed to the higher levels of copper in the reclaimed site. The range of copper concentration amongst the study sites however agrees with the findings from the study by Eddy *et al*. (2006), which puts the natural range for concentration of copper in a soil at 7 - 80 mg/kg. So therefore, despite the fact that the control site had the minimum value with the reclaimed sites emerging with higher values, we could conclude that the level of copper in the soil is good enough to support plant growth.

CONCLUSION

This study assessed the effectiveness of reclamation activities on restoring the nutrient levels of degraded mine sites within the Western region of Ghana. When land is surface-mined, the entire forest, including shrub layer, tree canopy, root stocks, seed pools, animals, and microorganisms, are removed with attendant effects on soil fertility and productivity. Reclamation is a widely accepted method for converting such degraded lands to productivity. With regards to the findings of this study, it can be concluded that the reclamation exercise has achieved some level of success at all the sites as the macro and micro nutrients concentrations are enough to support agricultural activities. It is recommended that the topsoil of high fertility status must be removed and kept safely during the mining operations and used again to spread over degraded site for quick regeneration of the fertility status of the soil and establishment of plants. Additionally, legumes with economic value such as cowpea, soybean, and groundnuts can also be used for the reclamation as they provide economic gain to the community members in addition to fixing nitrogen into the soil.

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