Heavy Metal Characteristics of Soils at the Damang-Abosso Mining Areas of Western Region, Ghana

Napoleon Jackson Mensah, Francis Ayiah-Mensah and Godfred Etsey Sebiawu

Abstract: This study analyzed the geochemical effect of mining activities on the quality of soils of selected mining areas of Western region in Ghana. In all nine heavy metals (Zn, Pb, Cd, As, Se, Ni, Ag, Co and Cr) concentrations were evaluated in eleven Soil samples from different locations using Atomic Absorption Spectrophotometer. The results of the present study revealed that all the heavy metals in the soil samples had their concentration within the recommended regulatory limits except Cadmium. Cadmuim concentration in the samples was higher than the recommended limits. It is envisaged that the results of this study would form the basis for further investigations into the effects of mining activities on the environment and eventual health implications of people.

Index Terms:. Mine waste, tailing, heavy metals, non-degradable, soil.

1 Introduction

Mining and industrial processing are among the main sources of heavy metals contamination in the environment. Heavy metals may accumulate to toxic level which can cause a potential risk to human health. Mines generate large volumes of waste including waste rock, slag, topsoil, overburden, tailing and all other associated materials that must be removed to access the mineral resource during extraction from the ore [1]. Mining tailing include waste generated during the extraction, beneficiation, and processing of minerals. One major problem of the mine is the handling and relocation of the large quantities of the resultant mine tailing. Mine tailings contains high concen-trations of heavy metals that are toxic and carcinogenic like Pb, Cu, As, Cd, Cr, Zn, Ni, and Hg [2], [3]. Heavy metals may be released from the mine tailing to the ground and surface water systems, as well as the geological environment due to their solubility and mobility.

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In view of the non-degradable nature of these metals, they maintain their persistency in the environment for a long time and therefore pose a serious problem to public health threat through their by existence in atmosphere and drinking water [2], [3], [4]. Moreover, the presence of excessive heavy metals in food, water, soil and in air have been implicated as potential environment contaminants leading to various human problem [5], [6], [7].

Pollution by heavy metals (Cd, Pb, etc.) affects not only the productivity of crops, but also the quality of the atmos-phere as well as water bodies and threatens the health and life of animals and human beings by way of the food chain. Many scientific studies have implicated heavy metals in the cause of dermatological diseases, skin cancer and internal cancers (liver, kidney, lung and bladder), cardiovascular disease, diabetes, and anaemia, as well as reproductive, developmental, immunological and neurological disorder in the human body [8], [9], [10], [11], [12], [13]. Heavy metal pollution occurs when such metals as arsenic, cobalt, copper, cadmium, lead, silver and zinc contained in excavated rock or exposed in an underground mine come in contact with water. The major environmental impacts from waste disposal at mine sites are the loss of productive land following its conversion to a waste storage area, and the introduction of sediment, acidity, and other contaminates into surrounding surface and groundwater from water running over exposed problematic or chemically reactive wastes [14].

The purpose of this research was to determination level contamination of the soil by heavy metals caused by dis-posal of mines waste at the Damang–Abosso areas of Western-region.

2. Study location

Damang-Abosso is located in Prestea-Huni Valley District which is about 33 Kilometers east of Tarkwa, the Prestea- Huni Valley District is a mining District which lies within the South Western Equatorial Zone and covers an area of about 1376 sqkm. According to the 2010 Population and Housing Census, the Prestea-Huni Valley District has a total population of 159,304 people. Out of this, 50.5% are males and 49.5 % female. Also, out of the total number about 63% of our people live in rural areas. The district has 4 major mining companies, Abosso Goldfields Ltd, Golden Star Resource, New Century Mines and Prestea Sankofa Gold Ltd.

Fig.1. Map of Southern Ghana indicating Damang-Abosso mining area circled red.

3. Methods and Materials

3.1. Sampling

Eleven soil samples were taken from different locations within the Damang-Abosso mining areas for analysis.

3.2. Digestion of Soil samples

A known of each sample (1g) was weighed and placed into 500 ml beaker followed by the addition of 10ml of di – acid mixture of HNO_3 and $HClO_4$ according to the ratio 9: 4 before a though mixing of the contents by swirling [15], [16].The flask with its contents was then placed on a hot plate in the fume chamber and heated, starting at 85^0C and then temperature raised to 150^0C. Heating was continued until the production of red NO_2 fumes ceased. The contents were further heated until volume was reduced to 3– 4 ml and became colourless or yellowish, but not dried. This was done to reduce interference by organic matter and to convert metal associated particulate to a form (the free metal) that could be determined by the Atomic Absorption Spectrophotometer (AAS model 220). Contents were cooled and volume made up with distilled water and filtered through Whatman 1 acid-washed filter paper. The resulting solution was preserved at 4^0C, used for Spectrophotometric determination of the various metals.

3.3 Atomic Absorption Spectrophotometry analysis.

AAS 220 model was used in determining the content of heavy metals in the previously digested tobacco samples. The acetylene gas and compressor were fixed and com-pressor turned on and the liquid trap blown to rid of any liquid trapped. The Extractor and the AAS 220 power were turned on. The capillary tube and nebulizer block were cleaned with cleansing wire and opening of the burner cleaned with an alignment card. The worksheet of the AAS software on the attached computer was opened and the hollow cathode lamp inserted in the lamp holder. The lamp was turned on; ray from cathode aligned to hit target area of the alignment card for optimal light throughput, then the machine was ignited. The capillary was placed in a 10 ml graduated cylinder containing deionized water and aspiration rate measured, and set to 6 ml per minute. The analytical blank was prepared, and a series of calibration solutions of known amounts of analyte element (standards) were made. The blank and standards were atomized in turn and their responses measured. A calibration graph was plotted for each of the solutions, after which the sample solutions were atomized and measured. The various metal concentrations from the sample solution were determined from the calibration, based on the absorbance obtained for the unknown (AOAC, 2006).

4.0 RESULTS AND DISCUSSION

Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as trace when less than 1000mg kg^{-1} and rarely toxic when in abundance [18], [19]. Mining and smelting have resulted in contamination of soil that poses risk to human and ecological health.

Zinc: Zinc is one of the essential elements for plants, microorganisms, animals, and humans. Exposure to high concentration of Zinc over long period of time may cause ad-verse health effect. However, Zinc is an essential nutrient needed for the growth of the body, bone, metabolism and wound healing. Therefore deficiency of Zinc can be detri-mental to the body. The concentration of Zinc (mg/kg) as shown in Table.1 below and range from 7.0 mg kg^{-1} to 15.0 mg kg^{-1} with an average of 11.45 $mgkg^{-1}$.The concen-tration of Zinc in the soil is far less than the recommended regulatory permissible limits of 20.0 mg kg^{-1} to 200.0 mg kg^{-1} as provided in Table 2.

Typical Cd and Zn contents of uncontaminated soils are less than 0.5 $mgkg^{-1}$ and 10-80$mgkg^{-1}$ [20]. Anthropogenic activity, such as mining activities, application of sewage sludge, industrial waste disposal and agricultural activity (fertilizers, pesticides) leads to local elevated Zn and Cd concentration in soils.

Lead: Lead is very toxic and can cause serious injury to the brain, nervous system, red blood cells, and kidneys [21]. Exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure. The risk of lead poisoning through the food chain increases as the soil lead level rises above this concentration. The concen-tration of lead (mg/kg) as shown in Table 1 below and range from 2.0$mgkg^{1}$ to 23.0$mgkg^{-1}$ with an average of 9.55$mgkg^{-1}$.The concentration of Lead in the soil is within the recommended regulatory permissible limits of 10.0mg kg^{-1} to 30.0mg kg^{-1} as provided in Table 2.

Research shows that levels of lead in the blood began to decline earlier in the western European and Scandinavian countries than in Eastern Europe, largely because unleaded petrol was gradually introduced earlier in these countries [22].

Cadmium: Cadmium is toxic and chronic exposure can led to kidney dysfunction. Food intake and tobacco smoking are the main routes by which Cadmium enters the body [23]. The concentration of Cadmium (mg/kg) as shown in Table 1 below and range from 1.6$mgkg^{-1}$ to 6.0 mg kg^{-1} with an average of 2.91$mgkg^{-1}$.The concentration of Cadmium in the soil is far above the recommended regulatory permissible limits of 1.0 $mgkg^{-1}$ as provided in Table 2.

In soil, the chemistry of cadmium is largely controlled by pH. Cadmium mobility and bioavailability are higher in more acidic soils, and lower in chalky/lime soils [24].

One way to reduce cadmium bioavailability is to lime the soil to make it less acidic. Research show levels of cadmium in smokers were six times those of non-smokers, a far more significant difference.

Arsenic: Arsenic exposure can cause skin damage, increased risk of cancer, and problems with circulatory system [25].The concentration of Arsenic (mg/kg) as shown in Table 1 below and range from 0.9mg kg^{-1} to 5.4$mgkg^{-1}$ with an average of 1.93$mgkg^{-1}$. The concentration of Arsenic in the soil is within the recommended regulatory permissible limits of 0.1 $mgkg^{-1}$ to 10.0$mgkg^{-1}$ as provided in Table 2.

Arsenicosis or arsenism is caused by prolonged exposure to low, non-lethal doses of arsenic, in the range of 0.005 to 0.09 milligrams per kilogram (mg/kg) of body weight per day [26]. The long list of other long term exposure effects includes peripheral neuropathy, gastrointestinal symptoms, conjunctivitis, diabetes, renal damage, an enlarged liver, bone marrow depression, destruction of red blood cells, high blood pressure and cardiovascular disease. In Cornwall, Phillip et al (1984) [27] found evidence of a cluster of malignant melanomas (skin cancers) among communities where local arsenic concentrations exceeded 30g/kg of soil.

Selenium: Selenium chronic exposure may result in im-proper functioning of endocrine, particularly on the synthesis of thyroid hormones [28].The concentration of Selenium (mg/kg) as shown in Table 1. Below and range from 0.91mgkg^{-1} to 0.6mgkg^{-1} with an average of 0.33mgkg^{-1}. The concentration of Selenium in the soil is within the recom-mended regulatory permissible limits of 0.1mg kg^{-1} to 2.0mgkg^{-1} as provided in Table 2.

High dietary intakes of selenium have been identified in parts of Venezuela, China and South Dakota, USA [24]. Symptoms in people with high urinary selenium levels in-cluded gastro-intestinal disturbances, discoloration of the skin and decayed teeth [24].

Nickel: Nickel at the right trace amount, is an essential mineral for human nutrition but it can be dangerous when the maximum tolerable amounts are exceeded. Nickel dermatitis is the most common effect in humans from chronic skin contact with nickel. Respiratory effects have also been researched in humans from inhalation exposure to nickel. The concentration of Nickel (mg/kg) as shown in Table 1 below and range from 0.2 mg kg^{-1} to 0.68mgkg^{-1} with an average of 0.45 mg kg^{-1}. The concentration of Nickel in the soil is far less than the recommended regulatory permissible limits as provided in Table 2.

A few studies have shown that small amount of nickel is probably essential to maintain proper health. The U.S Environmental Protection Agency recommends that children drink water containing not more than 0.04mg of nickel per litre of water for 1-10 days of exposure.

Workers whole inhaled very large amount of dust con-taining nickel compounds have lung and nassal sinus cancer. The effects of nickel exposure may depend on the type of exposure, concentration of the substance and the duration of exposure.

Silver: The concentration of Silver (mg/kg) as shown in Table 1 below and range from 0.1mgkg^{-1} to 0.6mgkg^{-1} with an average of 0.30mgkg^{-1}.

Cobalt: Cobalt is one of the essential elements for health but can also be a disadvantage in excessively high levels. The concentration of Cobalt (mg/kg) as shown in Table 1 below range from 0.1mgkg^{-1} to 0.70mgkg^{-1} with an average of 0.35mgkg^{-1}. The concentration of Cobalt in the soil is far less than the recommended regulatory permissible limits as provided in Table 2.

Chromium: Chronic Chromium exposure is associated with allergic dermatitis in humans [27].The concentration of Chromium (mg/kg) as shown in Table 1 below and range from 0.6mgkg^{-1} to 5.40mgkg^{-1} with an average of 2.83mgkg^{-1}. The concentration of Chromium in the soil is far less than the recommended regulatory limits as provided in Table 2.

5.0 Conclusion

It was realized from the research conducted that all the heavy metals contents measured satisfied the recommended permissible limit for soil exception of Cadmium which have its means far greater than the recommended permissible limits and this may be as result of high acidity content of the soil. It is envisaged that the results of this study will enrich the discussion and understanding of the effects of mining activities on the environment as well as the health implications of people.

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Labels	Zn mg/kg	Pb mg/kg	Cd mg/kg	As mg/kg	Se mg/kg	Ni mg/kg	Ag mg/kg	Co mg/kg	Cr mg/kg
SA 1	11.00	23.00	2.00	1.10	0.50	0.40	0.40	0.20	0.70
SA 2	8.00	7.00	5.00	5.40	0.40	0.40	0.10	0.20	4.30
SA 3	14.00	12.00	1.00	1.00	0.60	0.30	0.60	0.30	1.80
SA 4	14.00	2.00	2.00	1.50	0.40	0.40	0.20	0.30	2.20
SA 5	11.00	2.00	2.00	3.10	0.50	0.80	0.30	0.50	3.10
SA 6	14.00	12.00	2.00	0.90	0.10	0.30	0.30	0.40	2.70
SA 7	15.00	15.00	3.00	1.70	0.20	0.70	0.10	0.10	3.30
SA 8	8.00	2.00	3.00	2.20	0.20	0.70	0.40	0.70	5.40
SA 9	14.00	12.00	1.00	2.00	0.30	0.20	0.30	0.50	3.40
SA 10	10.00	11.00	6.00	1.10	0.20	0.50	0.10	0.30	3.60
SA 11	7.00	7.00	5.00	1.20	0.20	0.30	0.50	0.40	0.60
SAmean	11.45	9.55	2.91	1.53	0.33	0.45	0.30	0.35	2.83
SAmax	15.00	23.00	6.00	5.40	0.60	0.80	0.60	0.70	5.40
SAmin	7.00	2.00	1.00	0.90	0.10	0.20	0.10	0.10	0.60
STD Deviation	2.510795	6.439532	1.700267	1.32521	0.161808	0.196792	0.167332	0.169451	1.44782

Table 1. Shows contents of Heavy Metals in various samples of Soil.

Regulatory limits on heavy metals applied to Soils (Adapted from ADRIANO (2001). KABATA-PENDIAS (2000).

Heavy Element	Regulatory limits in mg/kg
Arsenic	0.1-10
Cadmium	0.05-1.0
Cobalt	1.0-10.0
Chromium	10.0-50.0
Copper	10.0-40.0
Iron	10000.0-50000.0
Lead	10.0-30.0
Mercury	0.05-0.5
Nickel	10.0-50.0
Selenium	0.1-2.0
Tin	0.1-10
Zinc	20-200

Table 2. Regulatory limits on heavy metals applied to Soils.

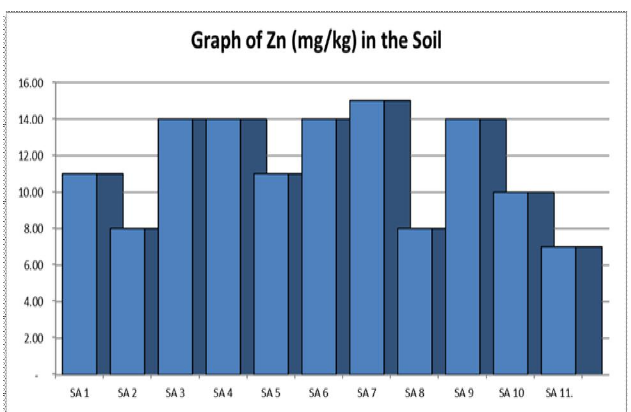

Figure 1. Shows a graph of Zinc contents in various samples of Soil.

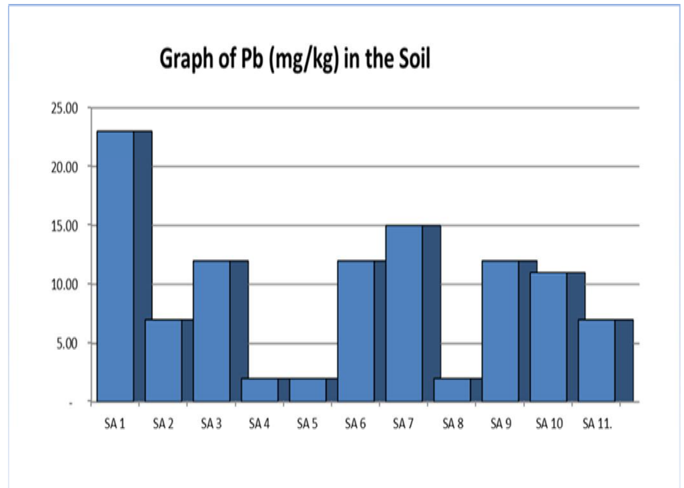

Figure 2. Shows a graph of Lead contents in various samples of Soil.

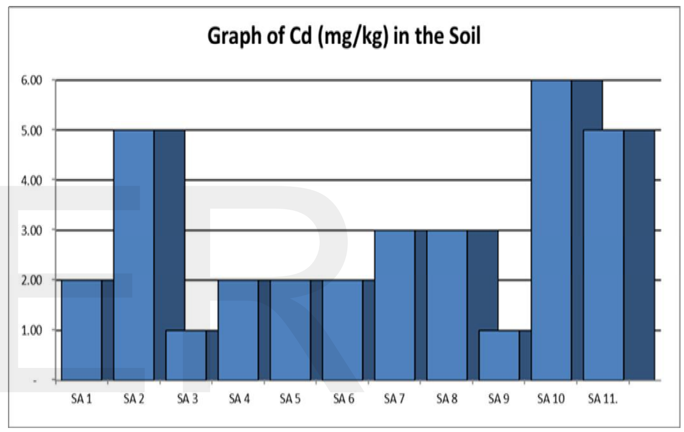

Figure 3. Shows a graph of Cadmium contents in various samples of Soil.

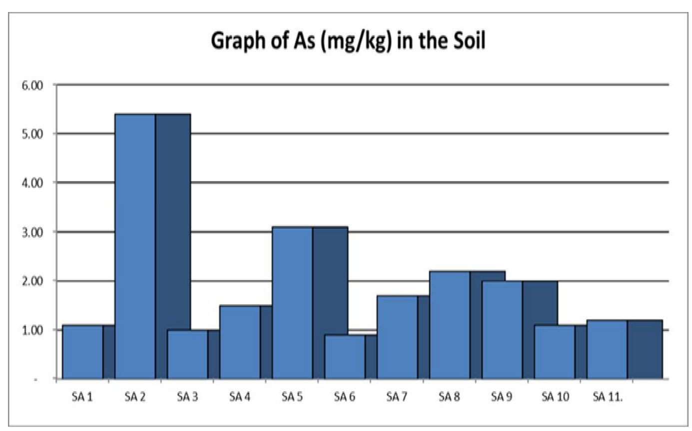

Figure 4. Shows a graph of arsenic contents in various samples of Soil.

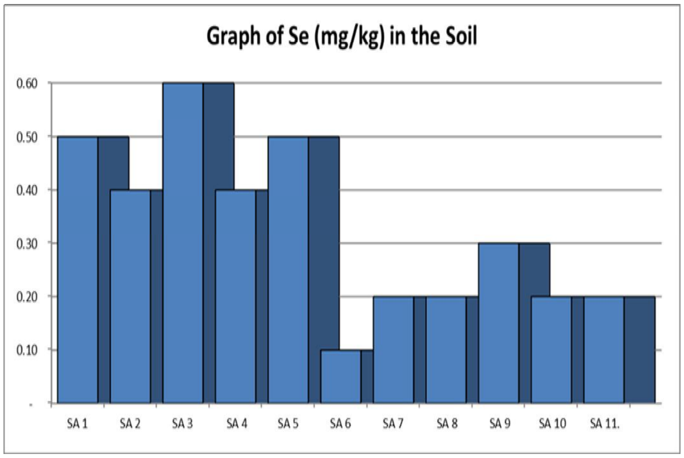

Figure 5. Shows a graph of Selenium contents in various samples of Soil.

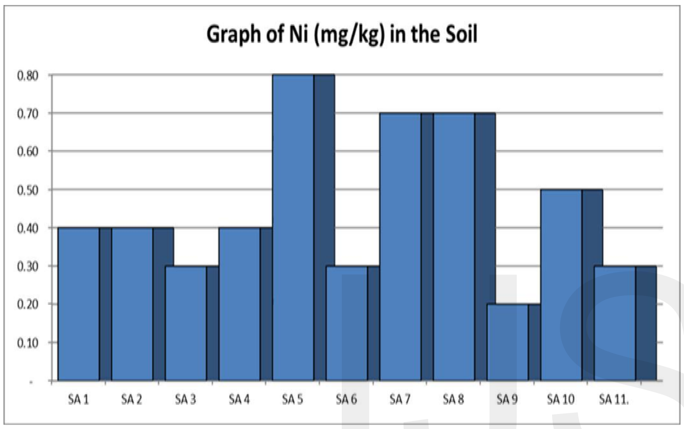

Figure 6. Shows a graph of Nickel contents in various samples of Soil.

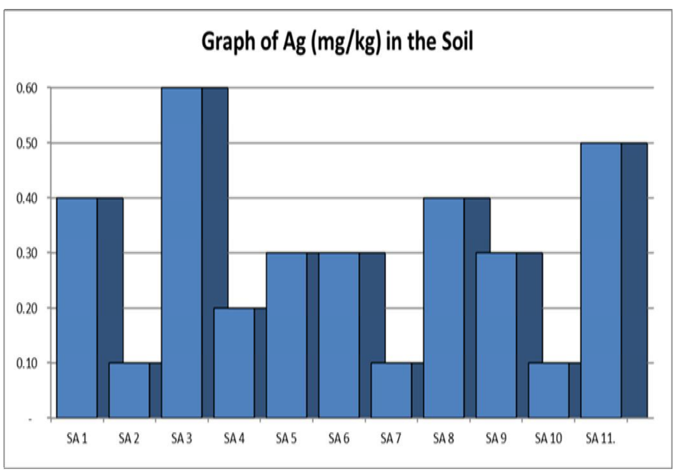

Figure 7. Shows a graph of Silver contents in various samples of Soil.

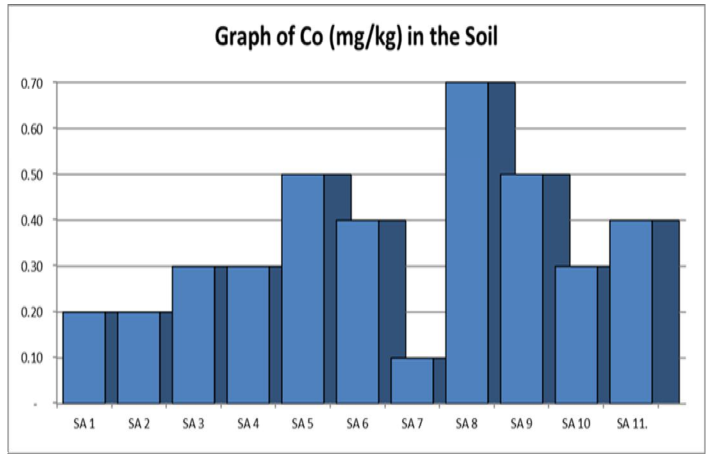

Figure 8. Shows a graph of Cobalt contents in various samples of Soil.

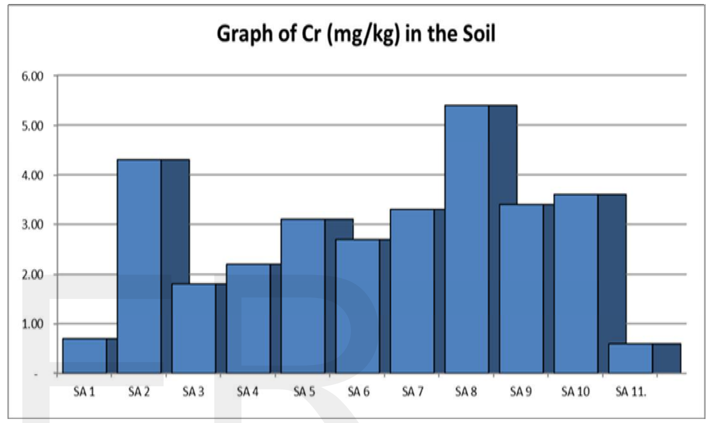

Figure 9. Shows a graph of Chromium contents in various samples of Soil.

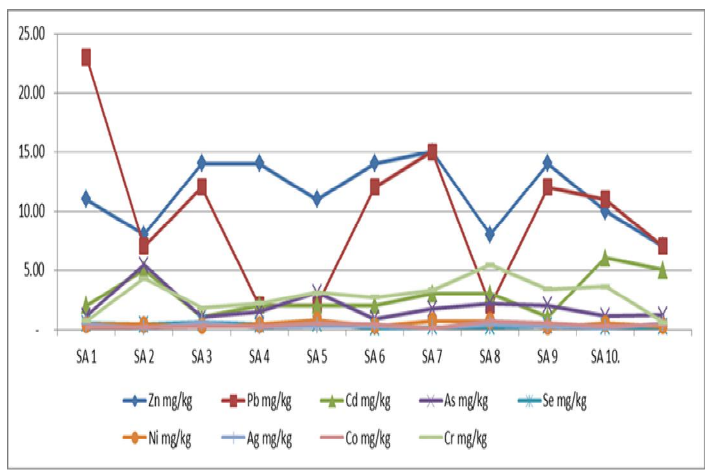

Figure 10. Shows a graph of heavy metals content in various samples of Soil.

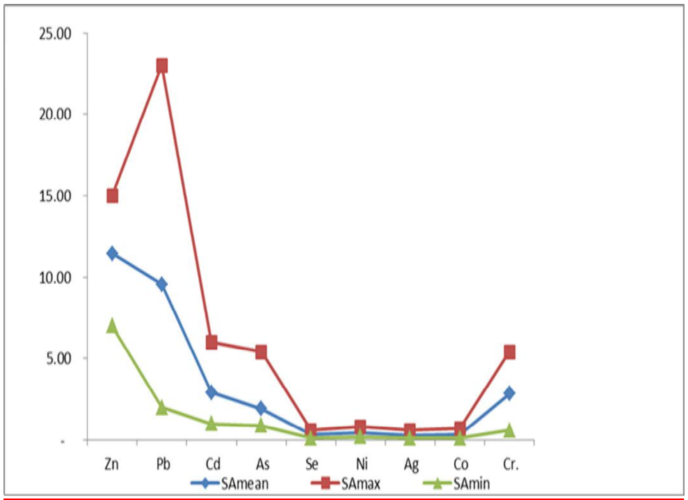

Figure 11. Shows a graph of mean, max and min of heavy metal contents in the Soil.