Investigating Heavy Metal Pollution in Soils at Tarkwa, Ghana

Abstract

The study was done at Tarkwa in the Western Region of Ghana which has a long history of mining activity. Soil samples were collected from 15 communities in the Tarkwa mining area and the concentrations in parts per million (ppm) of Mercury (Hg), Arsenic (As), Cadmium (Cd), and Lead (Pb) were determined in each sample using Instrumental Neutron Activation Analysis (INAA). Heavy metal concentrations of soils in the Tarkwa mining area were generally lower than expected of a typical mining area. The results of the study showed that except for isolated cases at Old Town, Akyempim, and Mile 10½ respectively, arsenic, cadmium, and mercury, levels in soil were far below the limits set by the International Atomic Energy Agency- Soil-7. Lead was within limits at all the sampling stations. It may, therefore, be concluded that contamination of soils by heavy metals is of no great significance in the study area. Periodic analysis of water sources in the area should be done to ascertain the concentration levels of heavy metals so that the local people as well as the miners could be advised accordingly.

Key Words: contamination, geochemistry, geology, infiltration, topography, concentration

Introduction

Globally, the overall impacts of mining activities are severe (Hilson, 2001) especially in areas where small scale mining is practiced. This is because most small scale miners do not use approved and scientific methods for mining and processing. There have been earlier reports that

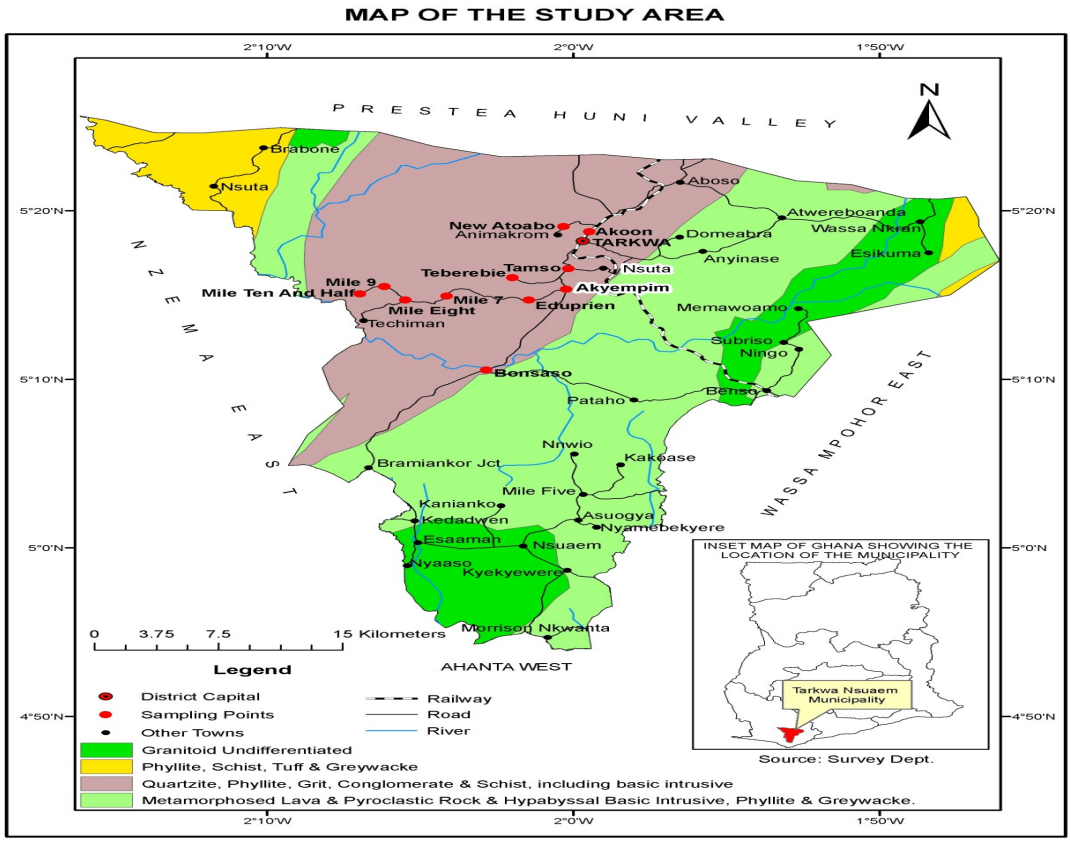
contamination of soils in mining areas depends on the geochemistry and the geology of an area over a period of time (Bell, 1998).

Most major towns in Tarkwa-Nauaem Municipality in the Western Region of Ghana rely solely on groundwater and so the number of boreholes and hand-dug wells are increasing rapidly to match the demand for portable water (Kortatsi, 2004). Surface water taken from the river Bonsa at Bonsaso is treated and distributed to Tarkwa town. Borehole yield varies from 0.4-18 m^3h^{-1} with an average of 2.4 m^3h^{-1}. The depth varies between 18 m to 75 m with an average of 35.4 (Kortatsi, 2004). The recharge of groundwater in the area occurs mainly by direct seepage or infiltration. In some places groundwater is in hydraulic contact with rivers and recharge from them can also take place (Kortatsi, 2004). A study by Ragnar and Bjorn (2005) showed that metal levels in ground water exceeded WHO guidelines for drinking water in many areas in the Western Region including Tarkwa where this study was done.

This study seeks to ascertain the level of heavy metal pollution of soils at Tarkwa which is a known mining town in Ghana and has a long history of small scale mining. The objective of the study was to investigate heavy metal pollution in soils in some selected communities of the Tarkwa-Nauaem Municipality in the Western Region of Ghana.

The study area

Tarkwa-Nauaem Municipality lies within latitudes 4°N and 5° 40”N, and 1° 45’ W and 2° 10’ W. The total land area of the district is 92,354 km^2 (Kusimi, 2007) (Fig 1) below.



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42 The geology of the Tarkwa mining area consists of a Basement complex, further divided into
43 different sub provinces including the metamorphosed and folded rocks of the Birimian and
44 Tarkwaian system. In several places, these systems are intruded by sills and dykes of igneous
45 rocks ranging from felsite and quartz porphyry to metadolerite, gabbro and norite (Kortatsi,
46 2004). The geomorphology of the area consists of a series of ridges and valleys parallel to each
47 other and to the strike of the rocks. The strikes of the rocks are generally in north-south direction
48 (Kortatsi, 2004). Both the Tarkwaian and Birimian systems are folded along axes that trend
49 northeast. The general type of topography reflects the underlying geology (Kortatsi, 2004).
50 There are two types of soil in the study area: the Forest Oxysols in the south, and the Forest
51 Ochrosol-oxysol integrates in the north (Kortatsi, 2004). The forest oxysols are porous, well
52 drained, and generally loamy-brown to orange. Due to heavy rains in the south, a high degree of

leaching and reduction of nutrients have occurred, making the soil acidic (Kortatsi, 2004). The soil consists mostly of silty-sands with minor patches of laterite, mainly on hilly areas (Kuma and Younger, 2001). The soil type distribution and their textures include: Banket (silty-sand Laterite), Tarkwa Phyllite (Laterite), Huni (silty-sand), Kawere (silt sand), and Weathered dyke (silt) (Kuma & Younger, 2001).

Research Methodology

Soil samples were collected from 15 communities in the Tarkwa mining area and the concentrations in parts per million (ppm) of Mercury (Hg), Arsenic (As), Cadmium (Cd), and Lead (Pb) were determined in each sample using Instrumental Neutron Activation Analysis (INAA). Analytical treatment of data was made in Excel, and Arcview.

Sample collection and preparation

Soil samples were collected from fifteen communities within the Tarkwa mining area. The soil samples were collected from farmlands at a depth of 0-20 cm using hand auger and plastic trowel. The samples were stored in dry polythene bags and sent to the Ghana Research Reactor-1 (GHARR-1) laboratory at Ghana Atomic Energy Commission (GAEC) for analysis. The samples were collected into clean plastic bottles (obtained after thorough rinsing) and carried to the GHARR-1 laboratory for analysis.

The soil samples were air dried for five days. They were then ground and homogenized after which they were sieved through a micro mesh of size 180 μm to obtain fine grains. 100 mg of soil sample was weighed in six folds for each test material on a clean polythene film, folded with forceps and heat-sealed with a air dryer. Each sample was in turn put into a rabbit capsule and smoothly heat-sealed with a soldering rod. Standard Reference Materials IAEA-Soil 7 and estuarine Sediment were equally weighed as the test samples.

The samples and the controls were irradiated at the Ghana Atomic Research Reactor-1 (GHARR-1) at the Ghana Atomic Energy Commission (GAEC), operating at 15KW at a thermal flux of 5×10^{11} n s^{-1} cm^{-2}. The samples were transferred into irradiation sites via pneumatic transfer system operating at a pressure of 0.60 mpa. The irradiation was done according to the half lives of the elements of interest. The soil samples were irradiated for one hour and delayed for 24 hrs, with 10 mins counting time.

After the irradiation, radioactivity measurement of the induced radionuclide was performed by a PC- based gamma ray spectrometry set-up which consists of an n-type HPGE detector, coupled to a computer based multi-channel analyzer (MCA) via electronic modules. The relative efficiency of the detector was 25% and its energy resolution was 1.8 keV at gamma ray energy of 1,332 keV, belonging to ^{60}Co. Through appropriate choice of cooling time, detector's dead time was controlled to be less than 10%. Identification of the gamma ray of product radionuclide was done using the energies and the quantitative analysis of the elements was achieved by the use of gamma ray spectrum analysis software, ORTEC MEASTRO-32. The quantitative analysis involved the conversion of the area under the photo peaks of the identified elements into concentrations.

For the determination of lead, 1.5 g of soil sample was digested in a microwave oven at a maximum power of 450 W for 10s, using a Teflon closed Parr bomb. The reagents used included a combination of 6.0 ml of 65% HNO_3, 3.0 ml of 35% HCl, and 0.25 ml of 30% H_2O_2. After that, samples were filtered carefully through Whatman 541, and quantitatively transferred into 50 ml plastic flasks and undertaken through AAS measurements.

Results and Discussion

The concentrations of arsenic, cadmium, mercury, and lead in µg/g for soil and mg/l for water as obtained from the laboratory analysis were sampled from different points and represented with the letters A-O (Fig 1).

The sampling points for the analysis were:

A= Mile 8, B= Naboaso (Tarkwa), C= Post Office Sq.(Tarkwa), D= Tamso, E=Eduprien, F= Awunaben Basin, G= Akoon, H= Akyempim, I= Teberebie, J= Mile 9, K= New Atuabo, L= Mile 7, M= Bonsaso, N= Mile 10½, O= Old Town (Tarkwa).

This discussion was based on the premise that quality control bodies such as International Atomic Energy Agency (IAEA) have come out with specific guidelines regarding heavy metal (trace element) concentration in soils; and that at concentrations higher than the guideline value, there is the possibility of plants (including crop plants) taking up these metals and eventually transferring them to humans through the food chain. Fig 2 below shows the concentration of Arsenic, Cadmium, Mercury, and Lead in soil samples picked at 15 locations within the Tarkwa Mining Area.

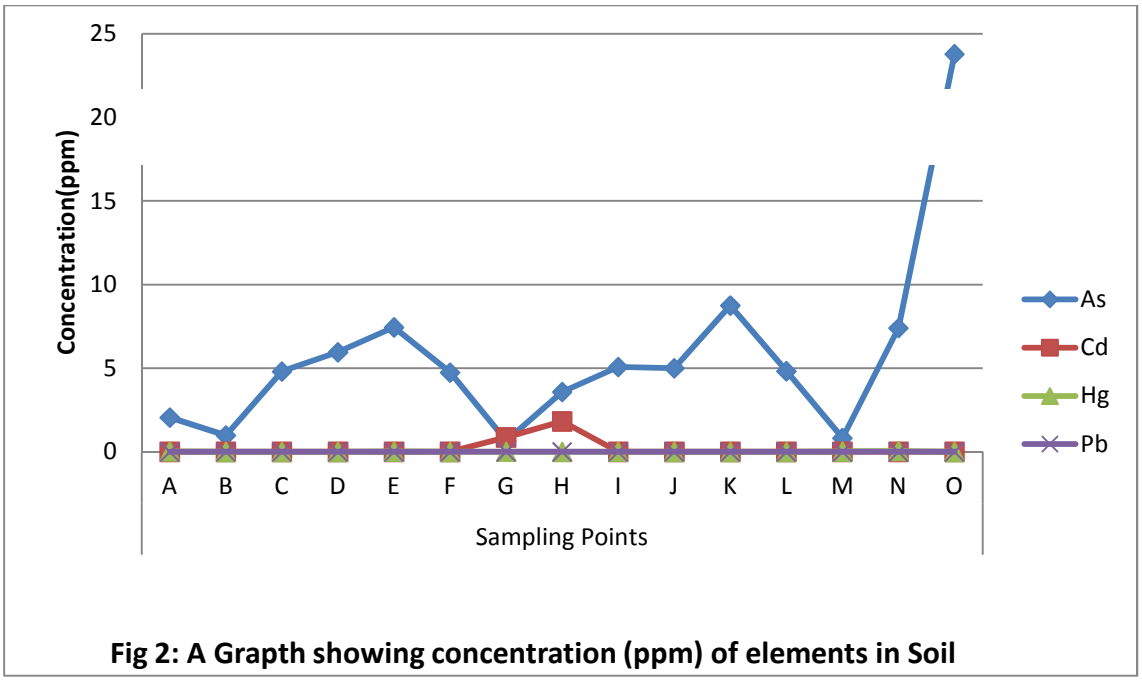

Fig 2: A Grapth showing concentration (ppm) of elements in Soil

Arsenic

Arsenic concentration in soil ranges from 0.65 µg/g to 23.78 µg/g (*Fig. 2)*.. The highest concentration was obtained at Old Town (Tarkwa). The second highest concentration (8.75 µg/g) occurred at New Atuabo. New Atuabo and Old Town lie along the same geological plane and so have the highest arsenic concentrations. Arsenic level in soil increased from Tamso (5.95 µg/g) to Eduprien (7.44 µg/g); it then decreased from Teberebie (5.07 µg/g) to Mile 9 (5.00 µg/g), and further to 4.82 µg/g at Mile 7. However, the concentration fluctuated again to 7.40 µg/g at Mile 10½. The decrease trend may be due to geological factors whilst the sharp increase could be blamed on some anthropogenic factors. The IAEA-Soil-7 recommended value for arsenic concentration in soils is 13.50 µg/g. This implies that all but only one station had soil arsenic levels below the IAEA guideline value. The high arsenic concentration recorded at Old Town was seen as an isolated case.

Mercury

High mercury concentration in soil (0.05 µg/g) occurred at Mile 10½. This was followed by Mile 8 which recorded 0.03 µg/g (*Fig. 2)*. The IAEA-Soil-7 recommended value for mercury level in soils is 0.04 µg/g. This means that all the stations have mercury levels within limits except Mile 10½ which had a concentration (0.05 µg/g) slightly above the recommended value. A critical observation of the trend of mercury occurrence in soils in the study area shows that mining activities, especially small scale mining operations, play a significant role in mercury concentration in soils in the study area.

Cadmium

Cadmium level in soils at all the stations was less than 0.01 µg/g except at Akyempim and Akoon which recorded 1.82 µg/g and 0.86 µ/g respectively (*Fig.2)*. The low concentrations could be due to geological factors. The IAEA-Soil-7 recommended value for cadmium concentration in soils is 1.30 µg/g. Akyempim had a concentration of 1.82 µg/g which is above the IAEA guideline value. A dose of 10 mg of Cadmium can produce symptoms of cadmium poisoning (ATSDR, 2007) and so plants must be monitored to avoid bioaccumulation in humans.

Lead

Lead concentration in all the samples was below 0.01 µg/g (*Fig. 2)*. The low concentration is probably due to the minute quantities in which lead minerals occur in the rocks of the area. The IAEA-Soil-7 recommended value for lead concentration in soils is 60.00 µg/g. This means that the recorded concentrations are far below the IAEA guideline value. Hence, no soil contamination in terms of lead is occurring in the study area.

Conclusions

Heavy metal concentrations in the Tarkwa mining area, especially in soils, were generally lower than expected of a typical mining area. The results of the study showed that except for isolated cases at Old Town, Akyempim, and Mile 10½ respectively, arsenic, cadmium, and mercury, levels in soil were far below the limits set by the International Atomic Energy Agency- Soil-7. Lead was within limits in at all the sampling stations. It may, therefore, be concluded that contamination of soils by the named heavy metals is of no great significance in the study area.

Recommendations

There should be intensified education on precautionary measures to be taken by miners, especially small scale miners (e.g. wearing of overalls, hand gloves etc., avoiding spillage, etc.) when dealing with chemicals such as mercury. Further research should be done on bioaccumulation of heavy metals in plants.

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