Geoaccumulation and Enrichment Factor of Some Elements in Soil Samples

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Abstract

Geo-accumulation index, enrichment factor, contamination factor and pollution load indexes were calculated in order to assess the presence and intensity of anthropogenic contaminant deposition on surface soil near the Myingyan Degree College for the element Si, Fe, Ca, Ti, Mn, Sr, Zr, and As. No arsenic pollution was found in the study area while strongly polluted by Sr and moderately to strongly polluted by Zr were found in the study area. Soil mineral elements like Fe, K, Ca, and Mn were found to be deficiency enrich while the Sr and Zr were moderately enrich in the soil. The element Sr has significantly contaminated in soil and the PLI value 3.25 indicates the soil quality is deteriorated.

Key words: Geo-accumulation index, enrichment factor, contamination factor, pollution load indexes

Introduction

Myanmar is an agricultural country and there are many agricultural fields and farmland at over the country. Myingyan district is located in the middle part of Myanmar, which is the dry zone. There are many farmlands near Myingyan Degree College, and the soils from the most farmland are found to be sandy. Nutrients and micronutrients elements are essential for basic growth and the development of plants. The concentrations of nutrients and micronutrients elements like K, Fe, Mn, Cu, and Zn in the soils are important for proper plants growth and functioning. The multi-elemental study of soils is needed in order to study the role of different elements in plant growth. Toxic heavy metals entering the ecosystem may lead togeo-accumulation, bio-accumulation and bio magnification. Heavy metals like Iron (Fe), Copper (Cu), Zinc (Zn), Nickel (Ni) and other trace elements are important for proper functioning of biological systems and their deficiency or excess could lead to a number of disorders (Ward,1995). Thus, it is important to investigate that there are no contaminants, which are toxic for the growth of plants. Soil pollution due to heavy and toxic metal contamination is a serious problem as there are toxic and their bio-accumulation capacity is very dangerous for its effects on food chain. Industrialization, urbanization and agricultural practices are the three main sources of metals in soils. The assessment of metal contamination is the most important for the human survival. This study focused on the study of elemental concentration and metal contamination in soils from farmlands near Myingyan Degree College. The assessment of soil contamination was based on geo-accumulation index (I_{geo}), enrichment factor (EF), contamination factor (CF) and pollution load indexes (PLI). The data on the distribution of metals in soils from farmlands near Myingyan Degree College will provide valuable information on risk and environmental pollution.

Study Area and Sample Collection

Five soil samples have been collected from five different farmlands near Myingyan Degree College. The location map for study area was shown in Figure (1). Sample 1 was collected from the farmland in front of the Degree College campus. Sample 2, 3, and 4 have been collected from the different farmlands that are North-West, North, and East of the

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campus respectively. Sample 5 has been collected from the farmland that is near the South-East of the campus. All collected samples are surface soils. All collected samples have been packed in plastic bags in order to prevent the mixing other impurities.

Figure (1) Location map for study area

Experimental Methods

The two experimental methods, Energy Dispersive X-rays Fluorescent EDXRF (EDX-700) and Atomic Absorption Spectroscopy (AAS), have been used to analyze the elemental composition of the soil samples. All collected soil samples have been measured in the Universities' Research Center, Yangon University.

Contamination Assessment

The Enrichment Factor (EF) in metals originally defined by Buat-Menard and Chesselet (1979) and Geo-accumulation index (I_{geo}) defined by Muller (1969) were used as indicators to assess the contamination of surface soils. These indexes of potential concentration in the surface soil respect to the concentration of a reference element. A reference element is an element particularly stable in the soil, which is characterized by absence of vertical mobility and (or) degradation phenomena. The most commonly used as reference elements in many studies are Aluminium (Al), Zirconium (Zr), Titanium (Ti), Iron (Fe) and Scandium (Sc) (Reiman and Decarital, 2000 and Blaser et al., 2000). Aluminium is a conservative element and a major constituent of clay minerals, and it has been used successfully by several scientists (Balls et al., 1997 and Sinex et al., 1988). Iron (Fe) has been used by many authors working on marine and estuarine sediments (Emmerson et al., 1997 and Lee et al., 1998). But Fe is not a matrix elements and its geochemistry is similar to that of many traces elements in oxic and anoxic environment (Barbieri et al., 2014). Elemental concentrations measured in a deeper soil horizon (subsoil) can be considered a local background for the upper soil horizon (surface soil) (Sutherland et al., 2000 and Blaser, 2000). The Enrichment Factor (EF) is calculated by using the formula:

$$EF = \frac{\left(C_x/C_{ref}\right)_{Sample}}{\left(B_x/B_{ref}\right)_{Background}}$$

Where, C_x is the concentration of the examined element in the sample, C_{ref} is the concentration of reference element in the sample, B_x is the concentration of examine element in the background sample,and B_{ref} is the concentration of the referenceelement in the background sample. Five contamination categories of EF were used in the study of soil quality state as shown in Table (1). In recent calculation, Iron (Fe) is used as reference element and IAEA-SOIL-7 is used as background sample.

Quantitative measurement of the extent of metal pollution in the studied soil was calculated by using geo-accumulation index. This index is expressed as follows:

$$I_{geo} = \log_2\left(\frac{C_n}{1.5 \times B_n}\right)$$

This I_{geo} index of metal is calculated by computing the base 2 logarithm of the measured total concentration of the metal over its background concentration. C_n is the average concentration of metal in the soil and B_n is the background concentration of the metal. The factor 1.5 allows us to analyze natural fluctuations in the content of a given substance in the environment and to detect very small anthropogenic influence. The degrees of metal pollution in terms of seven classes of I_{geo} index defined by Muller are shown in Table (2).

Table (1) Enrichment Factor (EF) categories

Value	Soil duct quality
EF < 2	Deficiency to minimal enrichment
2 < EF < 5	Moderate enrichment
5 < EF < 20	Significant enrichment
20 < EF < 40	Very high enrichment
EF > 40	Extremely high enrichment

Source: Barbieri M, GeolGeophys 2016, 5:1

Table (2) I_{geo} classes

I_{geo} Value	I_{geo} Class	Designation of soil quality
< 0	0	Uncontaminated
0-1	1	Uncontaminated to moderately contaminated
1-2	2	Moderately contaminated
2-3	3	Moderately to heavily contaminated
3-4	4	Heavily contaminated
4-5	5	Heavily to extremely contaminated
> 5	6	Extremely contaminated

The pollution load index (PLI) was also calculated in order to give proper assessment of the degree of contamination (Thomilson et al., 1980). The PLI represents the number of times by which the metal content in the soil exceeds the average natural background concentration, and gives a summative indication of the overall level of metal toxicity in a particular sample. The PLI of the place are calculated by using the following formula:

$$PLI = \left(CF_1 \times CF_2 \times CF_3 \times .... \times CF_n\right)^{\frac{1}{n}}$$

Where, n is the total number of metals. The total of nine metals (n = 9) have been studied in the recent paper. PLI < 1 implies that the site is free from contamination whilst, PLI = 1 implies to base line level of pollution and PLI > 1 is deterioration of site quality.

The individual impact of each trace metal on the soils can be represented by Contamination Factor (CF). The Contamination Factor (CF) is expressed as follow:

$$CF = \frac{C_x}{C_{ref}}$$

Where, C_x represents metal concentration in the studies environment and C_{ref} being that in the background environment. All the calculations have been done by using Microsoft Excel Version 2007.

Results and Discussion

The mean metal concentrations, the EF values, the I_{geo} values and their classes of the studied metals obtained in this study are shown in Table (3). The statistical data on pollution load index for five different soils samples are also shown in Table (4). The degree of metal pollution of soil samples according to geo-accumulation index and enrichment factor are shown as bar-graph in Figure (2).

Table (3) Metal concentrations and indexes of potential contamination

Elements	Mean Concentration (mg/kg)	EF	I_{geo}	I_{geo} Class
Si	760904	0.8426	1.49	2
Fe	128934	1	1.74	2
K	45880	0.75579	1.34	2
Ca	37914	0.04636	-2.69	0
Ti	15410	1.02388	1.78	2
Mn	2918	0.92177	1.62	2
Sr	1720	3.17446	3.41	4
Zr	2076	2.23677	2.90	3
As*	7.609	0.11318	-1.40	0

*AAS result

Table (4) Statistical parameters on the PLI values

Quantity	Min	Max	Mean	Standard Deviation	CV(%)
PLI	3.00	3.58	3.25	0.23	7.06

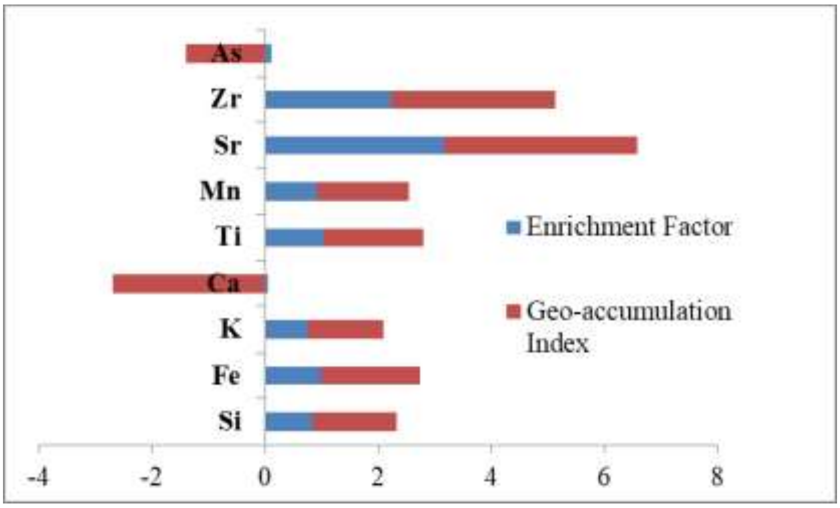

Figure (2) Bar-graph for Enrichment Factor and Geo-accumulation Index

The mean concentration of elements in the measured samples was found in the order of Si > Fe >Ca> Ti >Mn>Zr>Sr> As. The natural range for Iron (Fe) concentration in soil is 3,000 to 500,000 mg/kg. The mean Fe concentration is 128,934 mg/kg. The result obtained is within the natural Fe level for soil. The natural permissible limit for Potassium (K) concentration in soil is 200 to 24,000 mg/kg. The mean K concentration is 45,880 mg/kg. This result shows that the K concentration is more than the natural permissible limit. The permissible range for the concentration of Manganese (Mn) in soils is 200 to 9,000 mg/kg. The mean Mn concentration is 2,918 mg/kg. This is within the acceptable limit for the Mn concentration in soil. The range for Zirconium (Zr) concentration in soil is 5 to 1,060 mg/kg. The mean Zr concentration in the study is 2,076 mg/kg. It was observed that Zr concentration is more than the permissible limit.

The permissible limit for Arsenic (As) in soils for agricultural land is less than 20 mg/kg. The mean As concentration is 7.609 mg/kg. This result shows that although very few amount of Arsenic was found in the study area and its value is lower than the natural permissible limit.

The EF values for Si, Fe, K, Ca, Ti, Mn, and As observed in the recent study were found the deficiency to minimal enrich for these elements. It was also observed that the elementsSr and Zr were moderately enrich in the study area, with the FE values between 2 and 5. In general, it was found that the surface soils were negligibly enriched with these metals.

The I_{geo} class for Ca and As are zero so that they are uncontaminated in the study area. The elements Si, Fe, K, Ti, and Mn are moderately contaminated since their I_{geo} classes are 2. It was found that Zirconium (Zr) is moderately to strongly contaminated and Strontium (Sr) is strongly contaminated in the study area.

The Contamination Factor (CF) for Ca and As are less than one. These elements free from contamination in the study area. For the other elements like Fe, Ti, Mn, Sr, and Zr are contaminated in the study area because of their contamination factors are greater than one.

The PLI values ranged from 3 to 3.58, with the mean value of 3.25 have been observed in the recent paper. It was found that some of the study metals exceeded the background metal concentration. The overall contamination of soils at the study area assessed based on CF indicated considerable contamination by Sr and Zr, moderately contamination by Si, Fe, K, Ti, and Mn.

Conclusion

Some of the nutrient and micronutrient elements like K, Ca, Fe, and Mn are deficiency enrichment in the study area. This shows that the soils from the study area are deficiency of soil nutrients elements. Thus, it is not suitable for agricultural land. The radio isotopic elements Sr and Zr are moderately enrich in the study area. Based on I_{geo} index, the soil was graded as unpolluted by Ca and As. Calcium and Arsenic show no significant contamination in the soil. The soil was strongly polluted by Strontium (Sr) while, moderately to strongly polluted by Zirconium (Zr). The PLI value 3.25 indicates the soil quality is deteriorated. It can be concluded that the soil quality control must be done for using a land as an agricultural site.

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