

Research article

Application of Enrichment Factor for Assessment of Zinc Enrichment and Depletion in Farming Soils of Nigeria

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Abstract

Zinc (Zn) content was evaluated of the arable soils in the vicinity of mining and dumping sites in Nigeria. Its content the arable soils assayed by means of atomic absorption spectrophotometry (AAS) ranged from 48.3 to 280.4mg/kg. The enrichment factor (EF) calculated by using calcium as a crustal reference element fell within a range of 5.5 – 38.6. The mean values of the enrichment factor of 12.33 classified the soil as significantly contaminated with zinc. Anthropogenic activities contribute significantly to the elevated level of zinc in the studied areas. **Copyright © AJEPR, all rights reserved.**

Keywords: Zinc, Arable Soils, Enrichment, Depletion, Enrichment Factor, Anthropogenic Activities.

INTRODUCTION

Zinc is an essential plant micronutrient, indispensable to the proper growth of plants. Nearly 200 zinc – containing enzymes have been identified, including many dehydrogenases, aldolases, peptidases, polymerases and phosphatases, and hence, take part in the metabolism of carbohydrates, proteins, and phosphorus compounds; affect auxins synthesis, control ribosomes formation, affect the permeability of cell membrane; and increase plant resistance[1].

Zinc deficiency hinders plant growth, causes interveinal chlorosis and yellowing on young leaves, and reduces leaf size[2]. Soluble zinc forms are easily taken in by plants from soil, the extent of which depends on a plant type and prevailing soil conditions (soil pH and composition [3,4] Zinc is one of the most mobile elements in soil[5,6]. The factors that affect its increase are weathering of matrix, wet and dry atmospheric precipitation,

decomposition of living matter, and use of waste water in soil fertilization. At the same time, the enrichment processes are accompanied by leaching ones, which decreases zinc concentration in soil. The reduction may also result from its uptake by plants during a vegetation cycle[7]

Although, many metals are essential, all metals are toxic at higher concentration, because they cause oxidative stress by formation of free radicals. Another reason why metals may be toxic is that they can replace essential metals in pigments or enzymes disrupting their functions. Thus, metals render the soil unsuitable for plant growth and destroy the biodiversity[8]

The behaviour of a given element in soil (i.e., the determination of its accumulation or leaching) may be established by comparing concentrations of a trace element with a reference element[9,10] The result obtained is described as an enrichment factor (EF), and the equation used to calculate it is as follows:

$$EF = \frac{C_n / C_{ref}}{B_n / B_{ref}}$$

In which C_n is content of the examined element in the soil, C_{ref} is content of the examined element in the Earth's Crust, B_n is content of the reference element in the soil, and B_{ref} is content of the reference element in the Earth's Crust.

A reference element is "conservative" (i.e., the one that content in samples originates almost exclusively from the Earth's Crust. The most common reference elements in the literature are aluminum (Al), Zirconium (Zr), Iron (Fe), Scandium (Sc), and Titanium (Ti) [11,12,13,14], although there are also attempts at using other elements (e.g., manganese (Mn) Loska et al., 1979), Chromium (Cr) [15,16]

Generally, the enrichment factor is used to assess soil contamination (enrichment), and its interpretation is as follows:

EF < 2 – depletion to minimal enrichment

EF 2 < 5 – moderate enrichment

EF 5 < 20 – significant enrichment

EF 20 < 40 – very high enrichment

EF > 40 – extremely high enrichment

(Sutherland, 2000).

Enrichment Factor can also be used to evaluate element depletion in soil[17]. All EF values less than one may indicate that leaching and consumption of an element take precedence over its accumulation in soil.

This work is aimed to evaluate zinc enrichment and depletion of arable soil in the vicinity of mining and dumping sites, on the basis of enrichment factor. The samples tested were collected from farming soils in the vicinity of mining and dumping sites, in North-West, North-Central and South-East geopolitical zones of Nigeria. The results were expected to explain which processes, accumulation, or leaching is dominant in the

area. The research also attempted to analyze the relationships between enrichment and depletion of the surface layer of soil and parameters such as soil pH and humus content.

MATERIALS AND METHODS

Locations of the Research

The study areas are within latitude 4⁰ and 14⁰ North and longitude 3⁰ and 15⁰ East, Nigeria. These include:

1. Yargalma farming soil, near local gold ore mining site in Bukkuyum, Zamfara State, North West, Nigeria.
2. Dareta arable soil, near gold/lead ores mining site in Anka, Zamfara State, North West, Nigeria.
3. Itakpe farming soil, near iron ore mining site in Okene, Kogi State, North Central, Nigeria.
4. Ray Field Resort farming soil near tin ore mining site in Jos South, Plateau State, North Central, Nigeria.
5. Udi farming soil, near coal mining site in Enugu East, Enugu State, South East, Nigeria.
6. Chalawa arable soil in the vicinity of tannery waste dumping site in Kumbotso, Kano State, North West, Nigeria.
7. Court Road farming soil, near general dumping site in Kumbotso, Kano State, North West, Nigeria.

The dominant formations in the area are carboniferous deposits with layers from the Tertiary and Quaternary Periods. The predominant types of soils in the study areas are arenosols and ultisols. In small areas, histosols occur.

The study areas are agricultural, industrial and mining communities. The farmland covers over 65% of the study areas. The farming activity in the study areas deals mainly with crop growing such as yam, cassava, maize, pepper, okra, leafy vegetables, cocoyam, rice, millet, guinea corn, tomatoes, carrot, lettuce and onions. The areas are dominated by extensive agriculture, industrial and mining activities.

Sample Collection and Analytical Procedure

The surface soil layer to a depth of 0 – 20cm (ploughing layer) was sampled with a shaft. The pH of the soils (figure 1) tested ranged from 4.1 – 8.1, indicating acidic, neutral and slightly alkaline. Humus content (figure 2) ranged from 0.6% - 4.6%. Zinc distribution skewed towards high frequency of low concentration (figure 3). It had a wide range of 48.3 – 280.4mg/kg, the biggest number of values being found in 74 – 98mg/kg range. Zinc concentrations increased considerably with increasing humus content and vice versa. An increase in pH also affected significantly zinc increase. The enrichment factors for the soil samples ranged over 5.5 – 38.6, indicating significant to very high enrichment. The mean enrichment factor of 12:33 classified the soil as significantly contaminated (figure 4). There was no zinc depletion in all the soil samples evaluated.

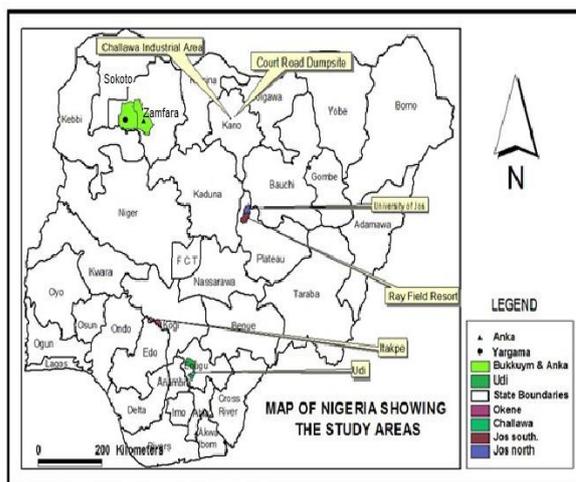


Figure 1.1: Map of Nigeria Showing the

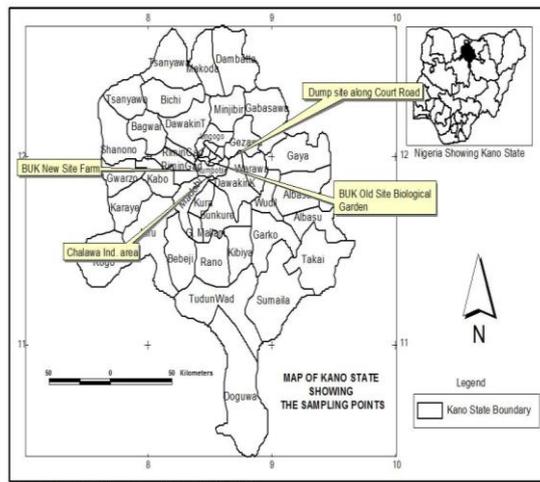


Figure 1.4: Map of Kano State Showing the

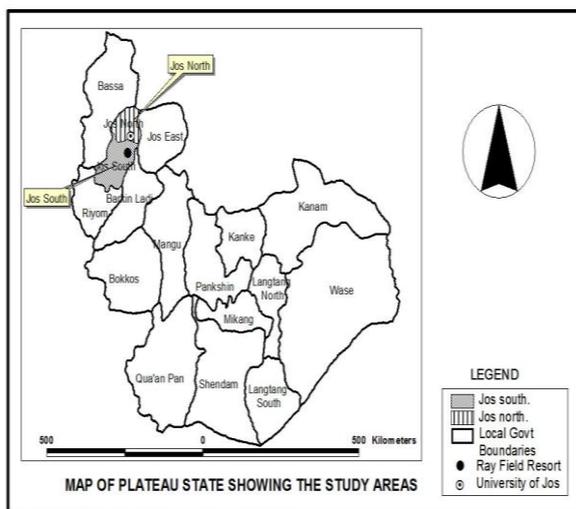


Figure 1.2: Map of Plateau State Showing

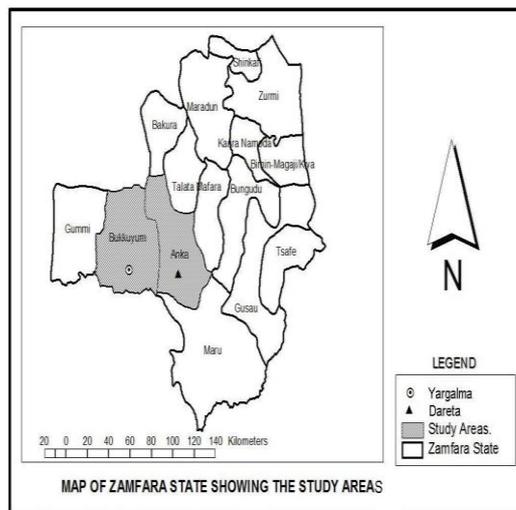


Figure 1.5: Map of Zamfara State Showing the Study Areas

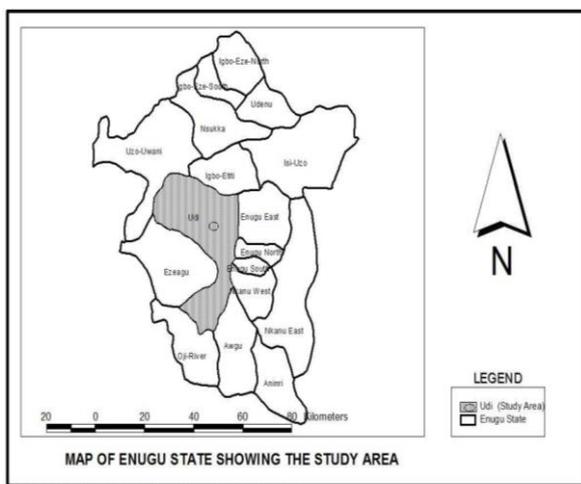


Figure 1.3: Map of Enugu State Showing the

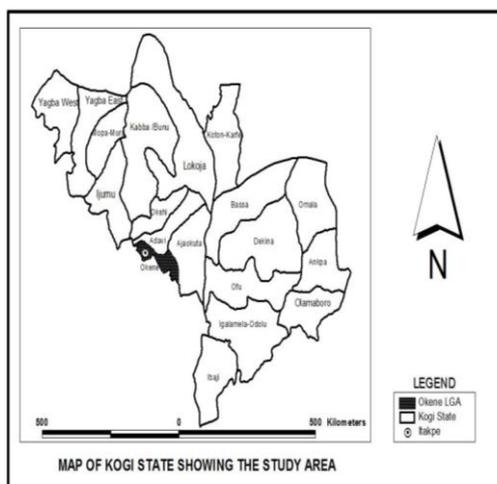


Figure 1.6: Map of Kogi State Showing the Study Area

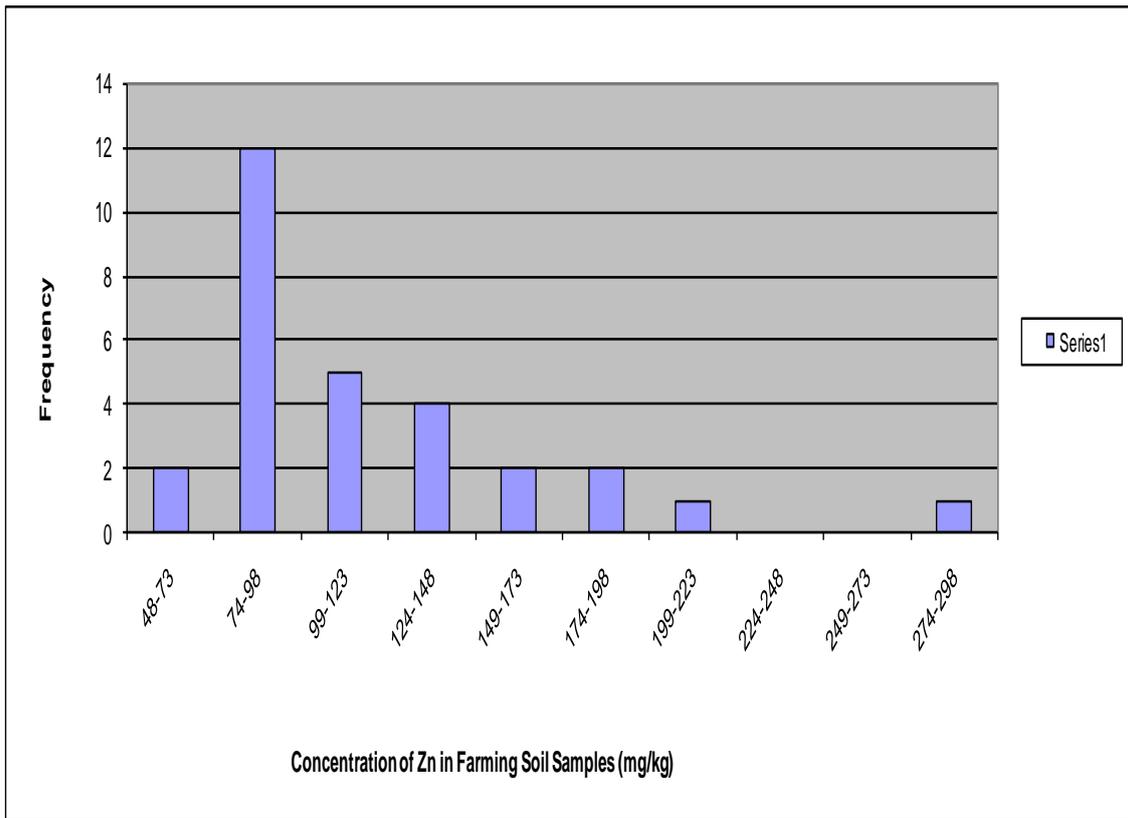


Figure 1.7 Frequency Distribution Pattern for Concentration of Zn in Farming Soil Samples

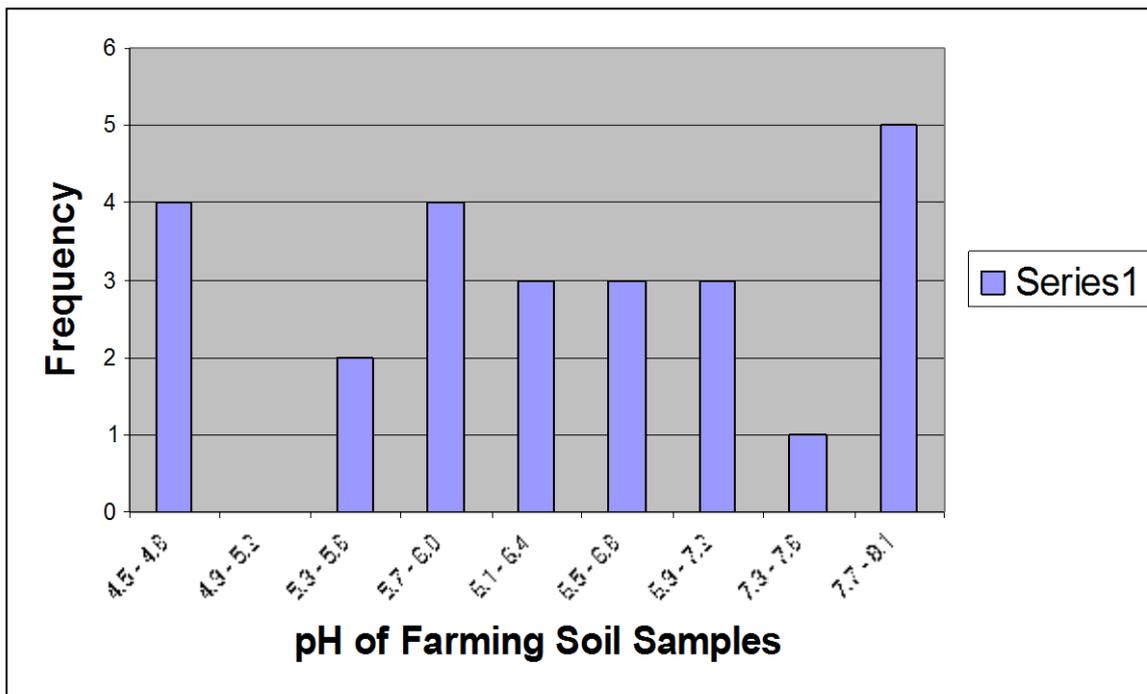


Figure 1.8: Distribution Pattern for pH in Farming Soil Samples

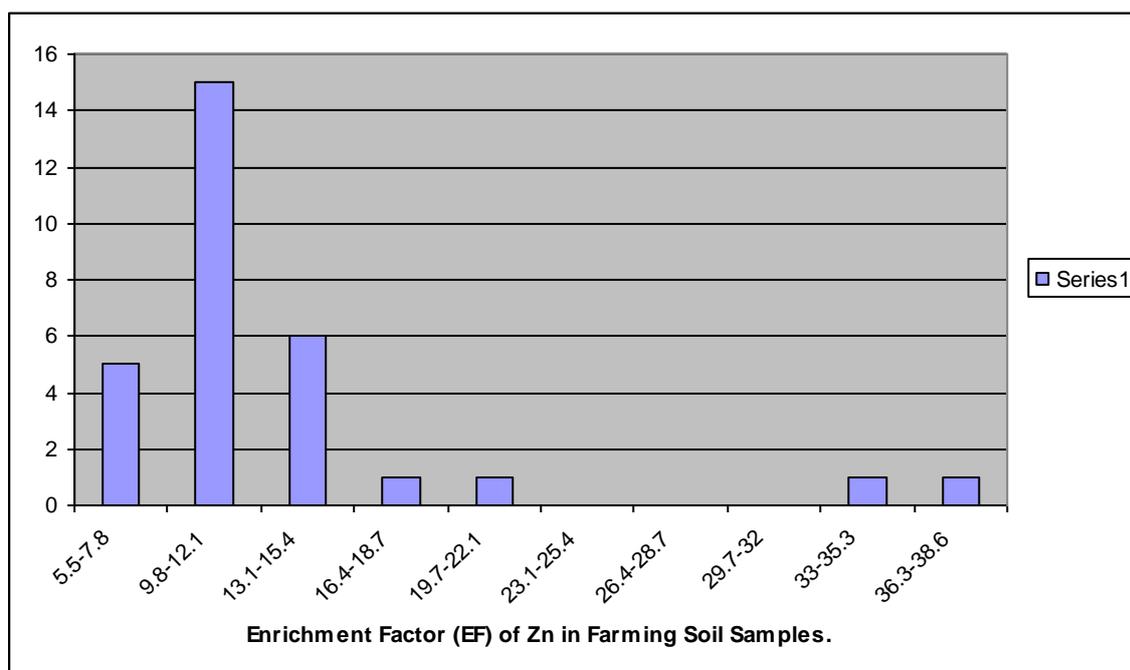


Figure 1.9: Frequency Distribution Pattern for Enrichment Factor of Zn in Farming Soil Samples, Using Ca as a Crustal Reference Element

DISCUSSION

The EFs obtained pointed to significant to very high enrichment. The mean enrichment factor of 12.33 classified the soil as significantly contaminated with zinc. The accumulation of zinc in these study areas are essentially due to anthropogenic influence. Most of the farmers make extensive use of fertilizers, cow dungs and tannery sludge as soil amendment materials. Accumulation of zinc in soils takes place in the surface layers using organic matter[2], which is composed of simple organic compounds and humus (i.e., large-molecular, dark-colored organic bonds). Humus, like simple organic compounds, readily accumulates metals, including zinc. The soils tested showed a distinct increase in zinc concentrations with increasing humus.

An increase in soil pH, on the other hand, results in an increase in EF. Thus, the increase in pH affects greatly zinc binding in soil and hinders its leaching. Humus content had a smaller effect on soil enrichment and depletion than pH.

Nigeria is one of the countries in West Africa most exposed to desert dust because of its proximity to the main emission source area and its location with regard to the dominant winds[18]. Studies have shown that harmattan dust which deposits on vegetations and farmland contains varying degrees of metal concentrations including zinc (Sunnu et al., 2008).

According to the Nigerian Federal Ministry of Environment (FME), there were 14 tanning industries around Challawa, one of the studied areas in Kano State by the year 2001, that discharge their liquid and solid wastes into the immediate environment (consisting of land and water bodies)[19], stated that various chemicals are used during the soaking, tanning and post tanning processing of hides and skins. The main chemicals used include

sodium sulphite and basic chromium sulphate including non-ionic wetting agents, bactericides, soda ash, CaO, ammonium sulphide, ammonium chloride and enzymes. Others are sodium bisulphate, sodium chlorite, NaCl, H₂SO₄, formic acid, sodium formate, sodium bicarbonate, vegetable tannins, syntans, resins, polyurethane, dyes, fat emulsions, pigments, binders, waxes, lacquers and formaldehyde. Various types of processes and finishing solvents and auxiliaries are used as well. It has been reported that only about 20% of the large number of Chemicals used in the tanning process is absorbed by leather, the rest is released as waste [20]. Tanneries have been found to discharge not only Cr which is an inherent product of the tanning process but also significant amounts of Zn, Mn, Cu and Pb, have been observed at the main waste disposal points exceeding the toxic range in soils[21]. This anthropogenic activities, contribute significantly to the elevated level of Zn in the studied area.

CONCLUSIONS

The locations of the studied zones in the anthropogenically affected areas are characterized by Zinc enrichment of all the tested soils, and in all cases well exceeding even 100% (EF > 2) against matrix. The dynamics of humus content, pH, prevailing environmental conditions and anthropogenic impacts, account for zinc accumulation in the studied areas.

REFERENCES

- [1] O' Dell B.L., History and Status of Zinc in Nutrition, Federation Proceedings, 43:2821-2822, (1994).
- [2] Kabata P.A. and Pendias H., Biochemistry of Trace Elements; Panstwowe Wydawnictwo Naukowe (in Polish): Warsaw, Poland. (1999)
- [3] Dudka S. and Chlopecka A., Effect of Solid-Phase Speciation on Metal Mobility and Phytoavailability in Sludge-Amended Soil Water, Air, and Soil Pollution, 51:153 – 160, (1990).
- [4] Rudd T., Lake D.L., Mehrotra J., Sterritt R.M., Kirk P.W.W., Campbell J.A. and Lester J.N., Characterisation of Metal Forms in Sewage Sludge by Chemical Extraction and Progressive Acidification, Science of the Total Environment, 74: 149 – 175, (1988).
- [5] Bergkvist B., Folkesson L., and Berggren D., Fluxes of Cu, Zn, Pb, Cd, Cr, and Ni in Temperate Forest Ecosystems, Water, air and Soil Pollution, 47:217 – 286, (1989)
- [6] Tyler L.D. and McBride M.B., Mobility and Extractability of Cadmium, Copper, Nickel, and Zinc in Organic and Mineral Soil Columns, Soil Science, 134: 198 – 205, (1982).
- [7] Goldschmidt V.M. Geochemistry; Oxford at Clarendon Press: London, 730, (1954)
- [8] Ghosh M. and Singh S.P., A Review on Phytoremediation of Heavy Metals and Utilization of its Byproducts, Applied Ecol. Environ. Res. 73:1-18, (2005).
- [9] Blaser P., Zimmermann S., Luster J. and Shotyk W., Critical Examination of Trace Element Enrichments and Depletions in Soils: As, Cr, Cu, Ni, Pb, and Zn in Swiss Forest Soils, Science of the Total Environment, 249:257 – 280, (2000).
- [10] Reimann C. and de Caritat P., Intrinsic Flaws of Element Enrichment Factors (EFs) in Environmental Geochemistry, Environmental Science and Technology, 34: 5084 – 5091, (2000)
- [11] Schiff K.C. and Weisberg S.B., Iron as a Reference Element for Determining Trace Metal Enrichment in southern California Coastal Shelf Sediments, Marine Environmental Research, 48: 161 – 176, (1999).

- [12] Schropp S.J., Lewis F.G., Windom H.L., Ryan J.D., Calder F.D. and Burney L.C., Interpretation of Metal concentrations in Estuarine Sediments of Florida Using Aluminum as a Reference Element, *Estuaries*, 13: 227 – 235, (1990)
- [13] Loska K., Cebula J., Pelczer J., Wiechula D. and Kwapuliński J., Use of Enrichment and Contamination Factors Together with Geoaccumulation Indexes to Evaluate the Content of Cd, Cu, and Ni in the Rybnik Water Reservoir in Poland. *Water Air, and Soil Pollution*, 93:347-365, (1997).
- [14] McMurtry G.M., Wiltshire J.C. and Kauahikaua J.P., Heavy Metal Anomalies in Coastal Sediments of Oahu, Hawaii, *Pacific Science*, 49: 452 – 470 (1995).
- [15] Loring D.H., Lithium: A New Approach for the Granulometric Normalization of Trace Metal Data. *Marine Chemistry*, 29: 155-168, (1990).
- [16] Mason B.J., Preparation of Soil Sampling Protocol: Technique and Strategies, EPA – 600/4-83-020, (1983).
- [17] Barth D.S. and Mason B.J., Soil Sampling Quality Assurance, Users Guide. EPA – 600/4-84-043, (1984).
- [18] Taylor S.R. and McLennan S.M., The Geochemical Evolution of the Continental Crust. *Reviews in Geophysics*, 33: 241: - 265, (1995).
- [19] Rutherford S., Clerk E., McTainsh G., Simpson R. and Mitchell C., Characteristics of Rural Dust Event Shown to Impact on Asthma Severity in Brisbane, Australia, *Int. J. Biometeorol* 42:217 – 25, (1999)
- [20] Sunnu A., Afeti G. and Reseh F.A., A Long Term Experimental Study of the Saharan Dust Presence in West Africa, *Atmos, Res.* 87: 13 – 26, (2008).
- [21] Imamul S.M., Critical Environmental Issues Relating to Tanning Industries in Bangladesh In: Naidu et al. (eds), *Towards Better Management of Soils Contaminated with Tannery Waste*, Proceedings of a Workshop Held at the Tamil Nadu Agricultural University, Coimbatore, India, 31st January to 4th February, 1998.
- [22] United Nations Industrial Development Organisation, UNIDO, Cost of Tanned Waste Treatment, 15th Session of the Leather and Leather Products Industry Panel, Leon, Mexico, (2005).