Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy 137 (2015) 589–600

Contents lists available at ScienceDirect

Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy

journal homepage: www.elsevier.com/locate/saa

Multivariate statistical analysis of heavy metal concentration in soils of Yelagiri Hills, Tamilnadu, India – Spectroscopical approach

A. Chandrasekaran [a], R. Ravisankar [b,*], N. Harikrishnan [b], K.K. Satapathy [c], M.V.R. Prasad [c], K.V. Kanagasabapathy [c]

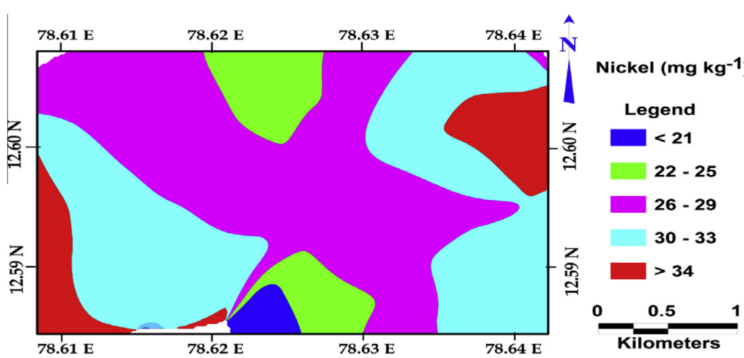
[a] Department of Physics, Vel Tech (Owned by RS Trust), Chennai 600062, Tamil Nadu, India
[b] Post Graduate and Research Department of Physics, Government Arts College, Thiruvanamalai 606603, Tamil Nadu, India
[c] EnSD, RSEG, Indira Gandhi Centre for Atomic Research (IGCAR), Kalpakkam, Tamil Nadu, India

HIGHLIGHTS

- Heavy metals concentrations were determined in soils using EDXRF.
- Heavy metal pollution is assessed by pollution indices.
- Quality of soil is assessed by Dutch soil quality guidelines.
- Spatial distribution of heavy metals is studied using statistical methods.

GRAPHICAL ABSTRACT

Spatial distribution of heavy metal nickel in different sampling points of soil samples from Yelagiri Hills, Tamilnadu.



ARTICLE INFO

Article history:
Received 19 June 2014
Received in revised form 6 August 2014
Accepted 24 August 2014
Available online 3 September 2014

Keywords:
Heavy metals
EDXRF
Statistical analysis
Enrichment factor
Geo-accumulation index
Spatial distribution

ABSTRACT

Anthropogenic activities increase the accumulation of heavy metals in the soil environment. Soil pollution significantly reduces environmental quality and affects the human health. In the present study soil samples were collected at different locations of Yelagiri Hills, Tamilnadu, India for heavy metal analysis. The samples were analyzed for twelve selected heavy metals (Mg, Al, K, Ca, Ti, Fe, V, Cr, Mn, Co, Ni and Zn) using energy dispersive X-ray fluorescence (EDXRF) spectroscopy. Heavy metals concentration in soil were investigated using enrichment factor (EF), geo-accumulation index (I_{geo}), contamination factor (CF) and pollution load index (PLI) to determine metal accumulation, distribution and its pollution status. Heavy metal toxicity risk was assessed using soil quality guidelines (SQGs) given by target and intervention values of Dutch soil standards. The concentration of Ni, Co, Zn, Cr, Mn, Fe, Ti, K, Al, Mg were mainly controlled by natural sources. Multivariate statistical methods such as correlation matrix, principal component analysis and cluster analysis were applied for the identification of heavy metal sources (anthropogenic/natural origin). Geo-statistical methods such as kirging identified hot spots of metal contamination in road areas influenced mainly by presence of natural rocks.

* Corresponding author. Tel.: +91 9840807356/9443520534.
E-mail address: ravisankarphysics@gmail.com (R. Ravisankar).

http://dx.doi.org/10.1016/j.saa.2014.08.093

Introduction

The earth crust contains major and trace elements such as Mg, Al, K, Ca, Ti, Fe, V, Cr, Mn, Co and Ni. Especially in earth crust, soil forms a major component of the ecosystem and is considered contaminated when alterations have been made to its natural environment [1]. The contamination of soil ecosystem with heavy metals is considered a global environmental issue. These heavy metals have both natural sources like weathering or/erosion of parent rocks and ore deposits and anthropogenic sources like mining, smelting, electroplating, fuel production, power transmission, intensive agriculture, waste water irrigation, sludge dumping and dust [2]. In the past century, anthropogenic activities especially mining and smelting have concentrated major elements like sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe) and aluminum (Al); and heavy metals likes chromium (Cr), cobalt (Co), vanadium (V), nickel (Ni), zinc (Zn) and manganese (Mn). In soil ecosystem, the toxicity and mobility of these metals depend on various factors like total concentration of metals, specific chemical form, metal binding state and properties. High concentration of elements from the atmospheric emissions also affects the ecological functions of soil [3].

Heavy metals are considered toxic to humans and ecosystems [2]. Heavy metal elements can be divided into essential and non-essential elements. Essential elements occur naturally in all organisms. In high doses essential elements also can be poisonous and cause hazardous effects on organism. The non-essential elements do not have any positive effects on organisms and they are harmful in low doses. They can inhibit an essential element to bind to enzyme and disturb the normal enzymatic function in the body. Hence soil quality investigation was necessary with a goal of finding the severity of soil metal pollution (agricultural and human activates) in the area and potential health hazard [4]. Heavy metal contents in soil are highly dependent on geochemical nature of parent material [5] and their presence in the soil is due to natural weathering of parent rock material and pedogenic processes. Conversely, their accumulation in the soil is of considerable importance because they are persistent, non-biodegradable and toxic to biota if they exceed threshold values.

The concentrations of heavy metals in environmental samples had been studied by several authors using either atomic absorption spectrometry (AAS) [5–9] or XRF analysis [10–15]. Most of these studies indicate high concentrations of heavy metals in the environment. Pollution of natural environment by heavy metal is a worldwide problem because these elements are indestructible and many of them have toxic effects on living organisms, especially when they exceed threshold values [16].

XRF is a rapid, non-destructive multi-elemental analysis technique with sensitivity in the range of few ppm to % [17] and it is ideal for environmental research. This analytical method has been widely and routinely applied to the analysis of various archeological samples, historical relics and works of art [15,18]. X-ray fluorescence (XRF) analysis is based on the measurement of characteristic X-rays resulting from de-excitation of inner shell vacancy produced in a sample by means of a suitable source of incident radiation. EDXRF analysis employs detectors that will directly measure the energy of the X-rays in a suitable detecting medium [19].

Geochemical study of soil is to evaluate the concentration of heavy metals that are necessary as it helps to assess the economic potential of soil. The concentration of heavy metals contamination can be classified into three types which are: (1) contamination indices – which compare the contaminations with the clean or polluted stations, measured elsewhere (2) background enrichments indices – which compare the results for the contaminations with baseline or background levels and (3) Ecological risk indices which compare the results for the contamination with quality guidelines [20]. Environmental quality indices are a powerful tool for development, evaluation and converging raw environmental information to decision makers, managers or for the public. Soil quality values are a useful tool to screen the potential for contaminants within soil to induce biological effects and compare soil contaminant concentration with corresponding quality guideline. Knowledge of the distribution and concentration of heavy metals in soil will help to detect the source of pollution in the study area.

In the last few years, anthropogenic activities like construction, waste disposal, domestic heating system and motor vehicles are continuously contributing toward an increase in the level of heavy metals in the tourist place, Yelagiri Hills, Tamilnadu. Hence an assessment is necessary to appraise the heavy metal concentration in the soil of Yelagiri Hills, Tamilnadu so as to understand the present condition of the soil quality and to compile the baseline data for future monitoring as there is no data on the distribution and concentration of heavy metals in soils of Yelagiri Hills, Tamilnadu.

Therefore, this study aims to quantify the heavy metals by EDXRF. To assess the soil pollution and toxicity due to major and heavy metal elements, enrichment factor (EF), geo-accumulation index (I_{geo}), contamination factor (CF) and pollution load index (PLI) are calculated and the spatial distribution of heavy metals is studied using multivariate statistical techniques and contour maps. Assessment of the heavy metal toxicity in the soils using Dutch soil quality guidelines (SQGs) is given in this paper.

Study area

Yelagiri (12.57°N; 78.64°E) is a hill station/village in Vellore district of Tamil Nadu, India, situated on the Vaniyambadi–Tirupattur road. Located at an altitude of 1410 m above Mean Sea Level and spread across 30 km^2, the Yelagiri village (also spelled Elagiri at times) is surrounded by orchards, rose-gardens, and green valleys. It comprises of 14 hamlets and a number of temples spread over couple of hills. The highest point in Yelagiri is the Swamimalai Hill, standing at 4338 ft: Swamimalai is a popular destination for trekkers. The hill provides a good number of trekking trails through thick reserve forests. Mangalam, a small village, is at the base of this hill. There are other trekking options that include smaller peaks like Javadi Hills and Palamathi Hills.

The hill station is located at 1048 m height. About 50% of the land area is red loam clay and sandy soil, roughly constituting 13% and 12% respectively, this type of soil is derived basically from feldspar and hornblende. The lithe-members of Yelagiri complex are intrusive into high grade country rocks viz. granite gneiss, amphibolite and pyroxene granulite. The country rocks are foliated bearing evidences of multiple folding and deformation. On the other hand, the constituent lithe members of the Yelagiri complex (senates, gabbro and later intrusive marked by lamprophyre and carbonate) show preservation of igneous layering in terms of discernible parallelism of the constituent minerals [21]. The Seasonal variations in the atmospheric temperature of Yelagiri Hills are not extreme and the place experiences pleasant climate throughout the year. The weather of Yelagiri Hills consists of summer, South East monsoon, North West monsoon and winter. The average maximum temperature that has been recorded is 30 °C and the average minimum is 18 °C. Yelagiri Hills has very hot climate during summer season with a maximum temperature of 35 °C during day time. Summer nights are relatively much cooler since the cool winds bring down the atmospheric temperature. The minimum temperature recorded during summer nights is 27.5 °C. The maximum temperature that has been recorded during monsoon is 25 °C