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Soil contamination evaluation by Enrichment Factor (EF) and Geoaccumulation Index (Igeo)

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Abstract

Heavy metals are natural constituents of soils and their concentration varies depending on parental materials. The soils were formed by. In the last years, the content of heavy metal in soils has increased due to human activities as: distribution of fertilizers, pesticides, industries, waste disposal and air pollution. Due to these activities the life capacity of soils decreased; especially where the natural background is already high because of natural parental material richness in heavy metal. As a matter of fact it is very important to distinguish between the natural background values and anthropogenic inputs, and to understand that the background values change from area to area and with the scale of the area investigated. To evaluate the soil contamination rate different indexes like Enrichment Factor (EF) and geoaccumulation index (Igeo) can be applied. These indexes are used to assess the presence and intensity of anthropogenic contaminant deposition on surface soil.

Keywords: *Enrichment Factor; Geoaccumulation Index; Soil;*

Introduction

Heavy metals, like As, Mn, Ni, Pb, Cd, may be very dangerous contamination factors for environmental state of soils, as they are not sensitive to any process of decomposition in soils and save themselves unaltered, also if they are transported by any, chemical, physical or biological process in any another environmental compartment. The presence of metals, at concentrations above certain thresholds, affects the microbiological balance of soils, and can decrease their fertility. Soil pollution due to heavy metals contamination is a serious problem as there are toxic and their bio-accumulation capacity is very dangerous for its effects on food chain.Heavy metals occur naturally in the soil environment from the pedogenetic processes of weathering of parent materials at levels that are regarded as trace (<1000 mg/kg) and rarely toxic [1]. Due to the human activities most soils as of industrial, as of rural and urban environments may accumulate one or more heavy metals. Many metals, such as Cu and Se, are essential elements for growth plant and for living organism, but high concentrations of these elements become toxic. Industrialization, urbanization and agricultural practices are the three main sources of metals in soils.

Heavy metals in the soil from anthropogenic sources tend to be more mobile, hence bio-available than pedogenic or lithogenic ones [2, 3]. Metal-bearing soils in contaminated sites can originate from a wide variety of anthropogenic activities in the form of metal mine tailings, disposal of high metal wastes in improperly protected landfills, leaded gasoline and lead-based paints, land application of fertilizer, animal manures, biosolids (sewage sludge), compost, pesticides, coal combustion residues, petrochemicals, and atmospheric deposition [1]. It is estimated that the contribution of metals from anthropogenic sources in soils is higher than the contribution from natural ones [4]. Many authors [5, 6] observed significant increases in soil metal content not only in areas of high industrial activity but also in areas far from industrial centres, due to long-range atmospheric transport. The assessment of metal contamination is most important for the human survival. The only determination of the rates of metals in the surface horizons of the soil cannot provide extensive indications about the state of contamination of soils. This kind of information does not allow the distinction between natural background and anthropogenic enrichment. Furthermore it must be evaluated the possible relationship with the characteristics of the substrate (parental material), and the use of the soil.
The natural content of heavy metals can vary in a large range depending on the material of which the soil has made of. Very important is the difference between background values and baseline values:

Background values: natural contents of substance in the soil completely dependent on the compositional and mineralogical characteristic of the parent/source geological material;
Baseline values: actual mostly diffuse range of concentration of an given element in a specific area dependent both on the nature of the parent geological/source material and on the historic diffuse release into the environment of contaminants from anthropogenic sources [7];

There are different indexes generally used to identify metal concentrations of environmental concern like: the metal enrichment factor (EF) and geoaccumulation indexes (Igeo) [8, 9]. These indexes identify, numerically, pollution level soils and normally they are calculated on the soil exchangeable fraction because it represents the real bio-available fraction. This fraction is obtained by applying the first step of Tessier procedure [10] and optimised by Frankowsky et al., 2010 [11]. The bio-available metal content in soil exerts a decisive impact on soil quality and it's used in food production. Hence, the assessment of metal contamination is of vital importance in farming areas.

Enrichement factor (EF) and Geoaccumulation Index (Igeo)

The Enrichment Factor (EF) in metals and Geoaccumulation Index (Igeo) (eq. 1 and 2) are indicators used to assess the presence and intensity of anthropogenic contaminant deposition on surface soil. These indexes of potential contamination are calculated by the normalization of one metal concentration in the topsoil 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 constituent chosen should also be associated with finer particles (related to grain size), and its concentration should not be anthropogenically altered [12]. Typical elements used in many studies are Al, Fe, Mn and Rb, and also total organic carbon and grain size are among those most used [12, 13, 14, 15]. Aluminium is a conservative element and a major constituent of clay minerals, and it has been used successfully by several scientists [16, 17, 18, 19]. Fe has been used by many authors working on marine and estuarine sediments [20, 21]. But Iron is not a matrix element and its geochemistry is similar to that of many traces elements in oxic and anoxic environment [19]. For many years the background values used were Earth crust and soil values [22, 23]. Some authors [7, 24] suggest that element concentrations measured in a deeper soil horizon (subsoil) can be considered a "local background" for the upper soil horizons. The Enrichment Factor is expressed as follow:

(1) $EF = (Metal/RE)_{soil}/(Metal/RE)_{background}$

Where, RE is the value of metal, adopted as Reference Element. The numerical results are indicative of different pollution level. Values of $0.5 \leq EF \leq 1.5$ suggest that the trace metal concentration may come entirely from natural weathering processes [25]. However, an $EF>1.5$ indicates that a significant portion of the trace metals was delivered from non- crustal materials [25, 26] so, these trace metals were delivered by other sources, like point and non-point pollution and biota [25, 27, 28]. With EF index, soil quality state can be indicate by different classes (table1) range from $EF<2$ (Deficiency to minimal enrichment) to $EF>40$ (Extremely high enrichment) [26].

The Geoaccumulation Index (Igeo) was originally defined by Müller (1979) [29] for metal concentrations in the 2-micron fraction and was developed or global standard shale values. This index is expressed as follows:

(2) $Igeo = \ln C_n/1.5*B_n$

Cn is the measured concentration of the element in soil dust, Bn is the geochemical background value and the constant 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.

Müller (1981) [30] has defined seven classes of Geoaccumulation Index (Table 2) ranging from Class 0 (Igeo=0, unpolluted) to Class 6 (Igeo>5, extremely polluted). The highest class (Class 6) reflects at least a 100-fold enrichment factor above background values.

Table 1: EF categories

Value	Soil dust 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	Extremaly high enrichment

Table 2: Igeo classes

Class	Value	Soil dust quality
0	Igeo≤0	Uncontaminated
1	0< Igeo <1	Uncontaminated to moderatelly contaminated
2	1< Igeo <2	Moderately contaminated
3	2< Igeo <3	Moderately to heavily contaminated
4	3< Igeo <4	Heavily contaminated
5	4< Igeo <5	Heavily to extremely contaminated
6	Igeo≥5	Extremely contaminated

Conclusions

Soil is a vital resource for humans because its chemical and physical conditions affect agricultural production and the quality of its products that constitute one of the fundamental factors of the life cycle of the earth. Depending on their concentration in the soil, the heavy metals may determine a potential toxicity to plants and for their consumers. Their entrance in the food chain represents a geochemical risk because of their toxicity to human health, especially to the occurrence of bioaccumulation phenomena.

Heavy metals can be present in the soil as a product of the weathering of the natural rocks, or because they come as part of pollution loads generated by human activities. It is very important to distinguish between the natural background values and anthropogenic inputs, and to recognize that the background values change from area to area and with the scale of the area investigated. For these reasons the geochemical monitoring of soil is important in the aim of evaluating the natural content of heavy metal in soils, related to parental materials and possible enrichment due to human activities.

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