

See discussions, stats, and author profiles for this publication at: <https://www.researchgate.net/publication/308792336>

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

Article · October 2015

DOI: 10.14616/sands-2015-3-9497

CITATIONS

0

READS

46

3 authors:



[Maurizio Barbieri](#)

Sapienza University of Rome

126 PUBLICATIONS 1,422 CITATIONS

[SEE PROFILE](#)



[Angela Nigro](#)

Sapienza University of Rome

16 PUBLICATIONS 4 CITATIONS

[SEE PROFILE](#)



[Giuseppe Sappa](#)

Sapienza University of Rome

118 PUBLICATIONS 137 CITATIONS

[SEE PROFILE](#)

Some of the authors of this publication are also working on these related projects:



SECOSUD II - Conservation and equitable use of biological diversity in the SADC region [View project](#)



Institutional Support to the management of Protected Areas in Albania funding from the International Union for Conservation of Nature (IUCN) [View project](#)

All content following this page was uploaded by [Angela Nigro](#) on 03 October 2016.

The user has requested enhancement of the downloaded file. All in-text references [underlined in blue](#) are added to the original document and are linked to publications on ResearchGate, letting you access and read them immediately.

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

Maurizio Barbieri¹, Angela Nigro¹, Giuseppe Sappa²

1) Department of Earth Science, Sapienza University of Rome, P.le A. Moro, 5 - 00185 Rome, Italy

2) Department of Civil, Building and Environmental Engineering, Sapienza University of Rome, Via Eudossiana - 00184 Rome, Italy

Corresponding author: Prof. Maurizio Barbieri, Tel +39-0649914593; e-mail: maurizio.barbieri@uniroma1.it

Article history

Received: September 24, 2015

Accepted: October 17, 2015

Published: October 21, 2015

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.

Enrichment 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:

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

Where, RE is the value of metal, adopted as Reference Element. The numerical results are indicative of different pollution level. Values of $0.5 \leq \text{EF} \leq 1.5$ suggest that the trace metal concentration may come entirely from natural weathering processes [25]. However, an $\text{EF} > 1.5$ 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 $\text{EF} < 2$ (Deficiency to minimal enrichment) to $\text{EF} > 40$ (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:

$$(2) \text{ Igeo} = \ln \text{ Cn} / 1.5 * \text{Bn}$$

C_n is the measured concentration of the element in soil dust, B_n 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 ($I_{geo}=0$, unpolluted) to Class 6 ($I_{geo}>5$, 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	$I_{geo} \leq 0$	Uncontaminated
1	$0 < I_{geo} < 1$	Uncontaminated to moderately contaminated
2	$1 < I_{geo} < 2$	Moderately contaminated
3	$2 < I_{geo} < 3$	Moderately to heavily contaminated
4	$3 < I_{geo} < 4$	Heavily contaminated
5	$4 < I_{geo} < 5$	Heavily to extremely contaminated
6	$I_{geo} \geq 5$	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.

References

1. Wuana R.A., Okieimen F.E. Heavy Metals in Contaminated Soils: A Review of Sources, Chemistry, Risks and Best Available Strategies for Remediation. ISRN Ecology International Scholarly Research Network. 2011,article ID 402647.

2. [Kuo S., Heilman P.E., Baker A.S. \(1983\) Distribution and forms of copper, zinc, cadmium, iron, and manganese in soils near a copper smelter. Soil Science, 1983; 135:101–109.](#)
3. [Basta N.T., Ryan J.A., Chaney R.L. Trace element chemistry in residual-treated soil: key concepts and metal bioavailability,” Journal of Environmental Quality, 2005; 34:49–63.](#)
4. [Nriagu J.O., Pacyna J.M. Quantitative assessment of worldwide contamination of air, water and soils by trace metals. Nature 1988; 333: 134–139.](#)
5. [Saur E., Juste C. Enrichment of trace elements from long- range aerosol transport in sandy podzolic soils of southwest france. Water, air and soil pollution, 1994; 73:235-246.](#)
6. [Steinnes E., Njastad O. \(1995\) Enrichment of metals in the organic surface layer of natural soil: identification of contributions from different sources. Analyst, 1995; 120: 1479–1483.](#)
7. [Feng H., Jiang H., Gao W., Weinstein M.P., Zhang Q., Zhang W., Yu L., Yuan D., Tao J. Metal contamination in sediments of the western Bohai Bay and adjacent estuaries, China. J. Environmental Management; 2011; 92: 1185–1197.](#)
8. [GIPME \(Global Investigation of Pollution in the Marine Environment\). Guidance on Assessment of Sediment Quality; 1999 IOCeUNEPeIMO, 23 pp.](#)
9. [Tessier A., Campbell P.G., Bisson M. Sequential extraction procedure for the speciation of particulate trace metals. Analytical Chemistry; 1979; 51: 844–851.](#)
10. [Frankowski M., Anetta Z.F., Kowalski A., Siepak J. Fractionation of heavy metals in bottom sediments using Tessier procedure. Environmental Earth Sciences, 2010; 60: 1165–1178.](#)
11. [Ackerman F. A procedure for correcting the grain size effect in heavy metal analyses of estuarine and coastal sediments. Environmental Technology Letters, 1980; 1: 518–527.](#)
12. [Allen J.R.L., Rae J.E.\(1987\)Late Flandrian shoreline oscillations in the Severn Estuary: a geomorphological and stratigraphical reconnaissance. Philosophical Transactions of Royal Society B Biological Sciences, 1987; 315:185–230.](#)
13. [Loring D.H. Lithium-a new approach for the granulometrical normalization of trace metal data. Marine Chemistry, 1990; 29:156–168.](#)
14. [Loring D.H., Naes K., Dahle S., Matishov G.G., Illin G. Arsenic, trace metals, and organic micro contaminants in sediments from the Pechora Sea, Russia. Marine Geology, 1995; 128:153–167.](#)
15. [Balls P.W., Hull S., Miller B.S., Pirie J.M., Proctor W. Trace metal in Scottish estuarine and coastal sediments. Marine Pollution Bulletin, 1997; 34:42–50.](#)
16. [Ryan J.D., Windom H.L. A geochemical and statistical approach for assessing metal pollution in coastal sediments. Metals in Coastal Environments of Latin America. Springer, Berlin Heidelberg, 1988; 47–58.](#)
17. [Sinex S.A., Wright D.A. Distribution of trace metals in the sediments and biota of Chesapeake Bay. Marine Pollution Bulletin, 1988; 19: 425–431.](#)
18. [Barbieri M., Sappa G., Vitale S., Parisse B., Battistel M. Soil control of trace metals concentrations in landfill: A case study of the largest landfill in Europe, Malagrotta, Rome. Journal of geochemical exploration, 2014; 143: 146-154.](#)
19. [Emmerson R.H.C., O'Reilly-Wiese S.B., Macleod C.L., Lester J.N. A multivariate assessment of metal distribution in intertidal sediments of the Blackwater Estuary, UK. Marine Pollution Bulletin, 1997; 34: 960–968.](#)
20. [Lee C.L., Fang M.D., Hsieh M.T. Characterization and distribution of metals in surficial sediments in Southwestern Taiwan. Marine Pollution Bulletin, 1998; 36: 464–471.](#)
21. [Martin J.M., Whitfield M. The significance of the river input of chemical elements to the ocean. In: Wong, C.S., Boyle, E., Brul, K.W., Burton, J.D., Goldberg, E.D. \(Eds.\), Trace Metals in Sea Water. Plenum Press, New York, 1983; 265–296.](#)
22. [Taylor S.R., McLennan S.M.The geochemical evolution of the continental crust. Review Geophysics, 1995; 33:241–265.](#)
23. [Blaser P., Zimmermann S., Luster J., 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 Total Environment, 2000; 249: 257–280.](#)
24. [Zhang J., Liu C.L. Riverine composition and estuarine geochemistry of particulate metals in China — weathering features, anthropogenic impact and chemical fluxes. Estuarine Coastal Shelf Science, 2002; 54:1051–1070.](#)
25. [Yongming H., Peixuan D., Junji C., Posmentier E.S. Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Cent, China. Science of Total Environment, 2006; 355:176–186.](#)
26. [Klerks P.L., Levinton J.S. Rapid evolution of metal resistance in a benthic oligochaete inhabiting a metal-polluted site. Biological Bulletin, 1989; 176:135–141.](#)
27. [Sutherland R.A., Tolosa C.A., Tack F.M.G., Verloo M.G. Characterization of selected element concentrations and enrichment ratios in background and anthropogenically impacted roadside areas. Archives of Environmental Contamination and Toxicology, 2000; 38: 428–438.](#)
28. [Müller G. Schwermetalle in den sedimenten des RheinseVeränderungen seitt 1971. Umschau 1979; 778–783.](#)
29. [Müller G. Die Schwermetallbelastung der sedimente des Neckars und seiner Nebenflüsse: eine Bestandsaufnahme. Chem. Ztg., 1981; 105: 157–164.](#)