Biogeochemical Mapping: A New Tool to Assess the Soil Quality and Health

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Abstract

Soil health is a recently established soil-biogeochemistry related concept. It has been defined as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans". As such, it can be considered as an approach to the consideration of soil as a living being. The parameters used to assess soil health are multiple, some of which are easy and cheap to measure, while others prove to be economically costly and time-consuming, as it is the case with the genetic identification and characterization of the microbiological communities, living in a certain soil, which represent the soil biodiversity and vitality. Other parameters can be considered as approximations to this concept. In this introduction to the concept, we consider to put forward three case studies. Two of them correspond to real "case studies", carried out in heavily polluted soils in relation with mining activity. As for the third study case, it corresponds to a recently funded project aimed to get a global view of the soil health relevant to the entirety of the South-Central Spain region.

Keywords

Biogeochemistry • Soil • Environment • Assessment • Case studies

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1 Introduction—Concepts of Soil Quality and Health

Soil has for long been intensively affected with human activities ever since the initiation of agricultural practices. In particular, modern agriculture, highly dependent on the use of phytosanitary products for the production of intensive crops, has deeply modified the biogeochemistry of soil. Such products prove to depend highly on both of the soil's inorganic composition, and on the biochemical activity developing on this substrate. On these bases, the soil quality concept turns out to be quite recognizable, implying the soil's characteristics which influence its agronomic productivity. Accordingly, a modern consensus definition should be: "the capacity of a soil to function, within ecosystem and land use boundaries, to sustain productivity, maintain environmental quality, and promote plant and animal health" [1]. Actually, the soil health concept is rather modern, most often defined as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals and humans" [2, 3]. This implies well identifying and quantifying the temporal evolution of quality, i.e., the productivity trends, based on the generalized supposition of a decay in productivity occurring in several soils exploited for extremely long-time spans, applying soil complements, but without any heed being paid to the soil-management related effects on the soil associated microbiota.

Soil quality has been traditionally assessed by means of classical edaphological parameters, including, the soil reactivity (pH), its soluble salt contents (electric conductivity, EC), its content in organic matter (SOM), texture, structure, among several other well-known concepts and via normalized analytical procedures.

Besides, soil geochemistry, which involves the implementation of chemical analysis of major and trace elements through different analytical techniques, helps provide valuable information as to the possibilities of soil use potentials. It also provides the possibility of detecting anomalous

D. M. Doronzo et al. (eds.), *Petrogenesis and Exploration of the Earth's Interior*, Advances in Science, Technology & Innovation, https://doi.org/10.1007/978-3-030-01575-6_1

(excessively high or excessively low) concentrations of the so-called "potentially toxic elements", including the alternative denominations of "heavy metals and metalloids" or similar, conditioning, via the "contaminated soil" concept, the agronomic possibilities of such soils.

Soil biochemistry has traditionally included the application of only a few basic parameters such as the SOM and/or other related parameters, including the total or available C, N and P contents. As for modern biochemistry, however, it includes a wider range of parameters, whose initial analyses have proved to demonstrate the importance of the related systematic monitoring, whereby soil quality and health could be effectively assessed, as basically supported by the biomass biodiversity.

On this basis, soil health assessment turns out to be rather focused on integrating and optimizing the soil's chemical, physical, and biological characters, very critical for sustained productivity and environmental quality to take place.

2 Assessment of Soil Quality and Health

As already stated, the parameters constituting the soil's classical "Edaphological parameters" are very well known, and the related measurement protocols are included in a wide range of general publications, with no important novelties being put forward over the last decades.

Geochemistry, on the other hand, has been marked with a drastic change in respect of the classical analytical-chemistry based primitive methods. Indeed, the newly advanced instrumental methods, displaying lower cost and analysis time consumption benefits, including the possibility of drawing reliable results directly from the solid samples, without the need for digesting the soil and, subsequently, diluting or handling the representative samples associated contamination risks, or getting errors in the analytical process. More particularly, the application of portable X Ray Fluorescence spectrometry has provided the possibility of reaching analytical results in real time, which could, in some cases, stand as an important tool, at least in respect of the previously implemented assessment methodology, whereby soil quality could be measured in terms of major-element contents, and possible soil contaminations detected in real time.

Biogeochemistry implies the determination of new parameters involving new technologies, whose economic cost has recently been marked with a remarkable decrease, such as the PCR technology (Polymerase Chain Reaction), or other even more recent approaches useful for identifying the soil persisting microbiological communities. Yet, other technologies, of simpler application, and/or lower cost, could still be applied in the preliminary assessment procedures. Worth citing among these includes are the soil respirometry, enzymatic activity, microbial biomass, to cite but a few.

3 Case Studies

Three case studies, corresponding to the region of Castilla-La Mancha (South-Central Spain), were selected to constitute our research study set, as specified below.

3.1 Geochemical Map of the Castilla-La Mancha Agricultural Soils

Castilla-La Mancha is an extensive region sited in South-Central Spain, characterized with a low degree of industrial development, with an economy primarily based on agricultural practices, predominantly based on oil and wine production. Bravo et al. present the results of a geochemical study based on the analysis of topsoil samples, as collected from 200 soil profiles, relevant to the region based agricultural areas [4]. More specifically, it consists in a model of geochemical maps, closely similar to the general atlas [5, 6]. This study has been subject of a research project funding provided by CLM Regional government, entitled "Soil biogeochemistry of Castilla-La Mancha region—Elaboration of thematic maps and setting of background- and reference levels". Accordingly, a total of 1000 additional samples of regional soils has be seleted and will be analyzed using XRF, and sequential extraction tests. The analyses will serve to stand as a recently updated geochemical data base, including the characterization of baseline and anomalous levels, along with reference values for risk assessment studies.

Besides, the project will include the recollection of 200 samples for biogeochemical analysis, including microbial biomass, soil respirometry, microbial metabolic coefficient (qCO_2) and enzymatic activity.

3.2 Mercury Contamination and Dehydrogenase Activity

Almadén is a town located SW the CLM region, globally known as the source origin of almost third of total mankind produced mercury. The mining production of cinnabar (HgS), the main and almost-ore bearing elements (together with sphalerite, ZnS, usually rich in this element) had been taking place for more than 2000 years, ever since the Roman times up until 2008. The ore had been processed through pyrometallurgy to obtain the liquid metal from a number of precincts, always enclosed to avoid robbery, due to the

element's high price. One of these precincts is that sited in Almadenejos, a village within some 15 km East of Almadén, and with minor Hg ore deposits. The precinct related activity started in 1750 and ceased in 1890, and has remained closed since then. Millán et al. analyzed soil respirometry in the area lying soils, while Campos et al. studied the distribution of dehydrogenase activity in the same area [7, 8]. Both of the studies reached results proved to demonstrate that the presence of highly elevated levels of total mercury, along with its most toxic species, methylmercury, did not appear to affect the measured parameters. Notworthy, however, is that the sites with higher Hg and MeHg contents inside the precinct proved to display a practical absence of vegetal cover, highlighting the possible effect of these toxics on vegetation and, probably, on certain bacterial communities. In this respect, we consider conducting a thorough investigation of the of these toxics presence on the soil quality and health.

3.3 Decommissioned San Quintín Pb–Ag Mining Area

San Quintín constituted to act as a relatively important mine, active during the late 19th Century and the early 20th Century, for the extraction of Ag-rich galena (PbS). Together with galena, the presence of other sulphides, including pyrite and sphalerite, as well as the lack of reclamation measures after the mine and froth flotation plant, has produced an intense environmental affection in the area [9]. Zamorano et al. analyzed diverse enzymatic activities on the different scenarios actually present in the affected area, including soils with different degree of PTEs' based contamination, old residua piles and dumps, etc. [10]. The analyses included DHA as well as the activities of β-galactosidase, acid- and alkaline phosphomonoesterase and urease. The attained results proved to reveal that the different scenarios have had null activity for certain enzymes, but normal activities for others, evidencing the presence of different bacterial communities, each living, most probably, in media supporting their specific nutrition requirements.

A similar study is being carried out by I. Mayel, from the University of Sfax, in the Trozza mine (the Kairouan region, central Tunisia), with DHA variability comparable to this found in San Quintín mine area.

4 Conclusions

The major conclusions to be retained following the conduction of this communication are mainly:

- Biogeochemistry stands presently as an important tool whereby soil health could be effectively assessed, commonly recognized as the soil-to-a-living-being approach.
- Biogeochemical parameters are still underway. Still, some of them can be interpreted properly in terms of microbiological health, i.e., in terms of appropriate biodiversity and vitality of the corresponding-soil persisting microbiological communities.
- The soil-health related assessment processes are having, and would continue to have, an increasingly greater importance iwith respect to the environmental oriented studies.

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