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Book Review

BIOPHYSICAL CHEMISTRY OF FRACTAL STRUCTURES AND PROCESSES IN ENVIRONMENTAL SYSTEMS

IUPAC Series on Analytical and Physical Chemistry of Environmental Systems
Volume 11

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The book is written by Nicola Senesi, professor of Soil Chemistry and Head of the Department of Agroforestal and Environmental Biology and Chemistry of the University of Bari, Italy and Kevin J. Wilkinson, PhD. in Environmental Chemistry from the National Water Research Institute of the University of Quebec, and Associate Professor of Chemistry at the University of Montreal.

The work is included in IUPAC series of Analytical and Physical Chemistry of Environmental Systems, which makes chemists, biologists, physics and other scientists aware of the most important biophysicochemical conditions and processes, which define the behaviour of environmental systems. The volume of the series focus on the use of fractal geometry to provide a quantitative description of disordered systems, such as environmental systems that, by their nature are obvious candidate for this kind of analysis.

Since fractal geometry provides a powerful approach for the quantitative description of disordered systems, it is useful for describing the processes that lead to the formation of such complex, highly irregular and random systems and their physical behaviour. In the natural environment, the need to describe quantitatively the complex physic-chemical systems is very actually. As a consequence of its practical utility for examining natural systems, fractal theory has developed in geophysical, toil and atmospheric science, although little critical discussion has attempted to relate the different fields.

Chapter 1, *Introduction to the Study of Environmental Fractals*, presents the most important notions and concepts, which have been shown to be useful to describe a large number of natural objects or/and systems and their physical, chemical and biological properties. Fractal geometry relates to structures that cannot be describes by Euclidian whole number dimensions, but instead have fractional dimensions. From this point of view, the environmental systems can be characterized in terms of several different fractal dimensions. Likewise, Chapter 1 brings in discussion the most common methods that have been proposed to estimate the fractal dimension of environmental systems: scattering techniques, turbidimetry, vapour adsorption methods, reaction rate methods and microscopy. Natural, real or random fractal are quasi or statistical self-similar oven a finite length scale, that is most often determined by the characterization technique that is employed. At the end of this chapter, are presented some conclusions and recommendations concerning to the possibility of use the fractal description in case of environmental systems.

Chapter 2, *Introduction to Fractal Geometry, Fragmentation Processes and Multifractal Measures: Theory and Operational Aspects of their Application to Natural Systems*, is focussed on the presentation of the most important aspects of fractal theory and multifractal measurements, from mathematical point of view, that have found application in environmental science. The structure adopted for the presentation is to follow a chronological description of the genesis of fractal geometry, starting with a number of strange-looking curves, discovered by mathematicians in the 19th century. In each case are presented the work hypothesis, mathematical description of these and the possibility of their application in the study of environmental systems.

Chapter 3, *Methods and Techniques for Fractal Analysis of Environmental Systems*, presents a summary of the techniques and methods which can be used for measuring of fractal dimensions of environmental systems. The choosing a certain technique depends on the particle being measured and by the environment in which they are being measured. Thus, small particles with size of the order of the wavelength of light or less are good candidate for light scattering experiments, whereas larger particles are suitable for optical microscopy and settling experiments. This chapter has illustrated how measurements from different particle characterization technique can be used for the determination of fractal dimension values. It is show that the state of the art in measurement of fractal dimension for environmental systems, in this moment, is probably confocal scanning laser microscopy (CSLM), because the analysis requires no models or assumptions and is free of the two-limitation of other imaging technique.

Chapter 4 deals with *Fractal Structures and Mechanisms in Coagulation/Flocculation Processes in Environmental Systems: Theoretical Aspects*.

The coagulation/flocculation, or more generally speaking aggregation, is the phenomena with a great importance in environmental systems, but also in many areas of chemistry, physics and industrial processes. Fractal concepts are traditionally used to describe aggregate structures, aggregation kinetics and setting velocity. In this chapter are presented, from qualitatively point of view, the most important factors which control the aggregation mechanism and some of aggregation models, which can appear in environmental systems. The influence of different factors on aggregation mechanism and their consequences, are also discusses. Unfortunately, in most of aggregation models presented here, is ignored the possibility of dissolved species adsorption and/or complexation, the role of hydrodynamic and magnetic interactions, etc., which make that the differences between theoretical and experimental results to be relatively high.

Chapter 5, *Fractal Mechanism in Coagulation/Flocculation Processes in Environmental Systems*, describe the elementary processes (such as: hydrolysis, surface complexation, adsorption etc.) occurs during of aggregation, and often determined the formation of fractals aggregates. In this chapter, the aggregation process is considered a very complex one, where elementary processes can occurs sometime in opposition. From this reason, the structural characterization of such systems requires the use of different experimental approaches, in the nanoscale and mesoscale size range. In particular, extended X-ray adsorption fine structure (EXAFS) and small-angle X-ray scattering (SAXS) techniques have demonstrated a good concordance between the aggregates structures and the fractal dimension of these. Both techniques allow the non-destructive, rapid and permit in situ structural determination of fractal aggregates.

Chapter 6, *Fractal Approach to Adsorption/Desorption Processes on Environmental Surfaces*, describes various applications of fractal concepts to the description of adsorption/desorption processes on environmental materials. The surface fractal dimension can be determined by several experimental methods, among which the method based on the adsorption measurements is the most convenient and straightforward. Particular attention has been paid to the discussion of the fractal approach used for the adsorption of gases on clay minerals and soils. The concept of "quenched – annealed" mixture has been widely used for the study of the structure and thermodynamic properties of gas fluids adsorption in disordered porous materials, like clay minerals and soil components. The novelty of this approach is that the structure of the porous materials can be included into the description of adsorption process by using a fractal structure factor of the adsorbent.

Chapter 7, *Applications of Fractals in the Study of Humic Materials*, analyses the fractal approach as ideally suited to the study of higher order structural organization and interactions in humic materials. Humic materials have been shown to be mass fractal aggregates in solution or in suspension, and surface fractals in the solid state. The fractal dimension of both fractal types are generally between 2 and 3, but the value of this varied in function of some parameters (pH, ionic strength, concentration of humic material, sample source, aggregate size, etc.). From this reason, the real value of fractal approach in the study of humic materials will not be realized until it can be applied in a manner that describes the properties, reactions or geochemical behaviour of these.

Chapter 8, *Fractal Geometry and Microorganisms in the Environment* shows the way in which fractal geometry can be used for the description of spatial distribution of microorganisms from microbial mass. By comparison with mycelial organisms under different conditions, in agar, soil and water, small differences that cannot be observed from visual observations or from other morphological description, is evidenced using fractal approach. Unfortunately, fractal dimension alone not offer a complete picture about the growth and distribution of microorganisms in biomass. From this reason, authors recommend the utilization of this together with linear extension rate analysis, for example, which will permit the characterization of vigorous organisms growing under favourable conditions. Further, other mathematical tools, such as graphing theory analysis, may be valuable adjuncts to fractal dimension, science they can quantify connectedness within different parts of systems, and can be used to examine effects of breaking connections.

Chapter 9 deals with *Fractal Geometry of Aerosols Particles*. Many physical characteristics of aerosols are determined by combinations of their size and morphology, and are crucial to the climate change debate.

The application of fractal geometry to aerosol science lies to the necessity to parameterise complex aerosol shapes, and has been an active research area for over 50 years. The in-situ experimental techniques, which can be used for the determination of the fractal dimension of both a single aggregate and assembles, are also presented. From engineering point of view, such measurements could provide rapid feedback on particle morphology and structure to monitor and control generation processes.

The fractal characterization of aerosols has received increasing attention in recent years. Thus several properties, such as hydrodynamic, diffusional, optical and elastic properties of aerosols can be successfully describes using fractal geometry. The fractal description of aerosols properties has a great importance in many industrial applications, where aerosol particles with a well-defined structure are needed, but also in climatic studies, where the fractal dimension of atmospheric aggregates offer information about the aerosol sources and their history.

Each chapter of the book contains a well documented list of references and a list of used notation.

The book aims to provide for the scientific community novel and valuable approaches based on fractal geometry concepts, which can be used for the quantitative description of complex, high irregular and random systems, such are environmental systems. The information presented in the book may be useful for the graduate students, scientists, researchers and professionals involved in fundamental and applied studies in environmental science.

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