WILEY

INTRODUCTION TO SOIL CHEMISTRY

Analysis and Instrumentation

Alfred R. Conklin

Chemical Analysis: A Series of Monographs on Analytical Chemistry and Its Applications

Introduction to Soil Chemistry

Analysis and Instrumentation

ALFRED R. CONKLIN, Jr.

WILEY-INTERSCIENCE

A JOHN WILEY & SONS, INC., PUBLICATION

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.
Published simultaneously in Canada.

Library of Congress Cataloging-in-Publication Data:

Conklin, Alfred Russel, 1941–
Introduction to soil chemistry : analysis and instrumentation / Alfred R. Conklin, Jr.
p. cm.
Includes bibliographical references and index.
ISBN-13 978-0-471-46056-5
ISBN-10 0-471-46056-7 (cloth)
I. Title.
S592.5.C655 2005
631.4′1—dc22 2004025912

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Introduction to Soil Chemistry

CHEMICAL ANALYSIS

A SERIES OF MONOGRAPHS ON ANALYTICAL CHEMISTRY AND ITS APPLICATIONS

Edited by
J. D. WINEFORDNER

VOLUME 167

This book is dedicated to my
wife Petra
son Russ
and
daughter Petal

PREFACE

The author is both a soil scientist and a chemist. He has taught courses in all areas of chemistry and soil science and has analyzed soil for organic and inorganic compounds in both soil solids and extracts, using various methods and instruments, for 37 years. *Introduction to Soil Chemistry: Analysis and Instrumentation* is the result of these 37 years of experience that have taken place in two distinct climatic zones in the Philippines, four countries in Africa, and one in Central America. In the United States it includes analysis of soils from all sections of the country.

This book is intended as a reference for chemists and environmentalists who find that they need to analyze soil, interpret soil analysis, or develop analytical or instrumental analysis for soil. Soil scientists will also find it valuable when confronted by soil analyses that are not correct or appear to be incorrect or when an analysis does not work at all.

There are two themes in this work: (1) that all soil is complex and (2) that all soil contains water. The complexity of soil cannot be overemphasized. It contains inorganic and organic atoms, ions, and molecules in the solid, liquid, and gaseous phases. All these phases are both in quasi-equilibrium with each other and constantly changing. This means that the analysis of soil is subject to complex interferences that are not commonly encountered in standard analytical problems. The overlap of emission or absorption bands in spectroscopic analysis is only one example of the types of interferences likely to be encountered.

Soil is the most complicated of materials and is essential to life. It may be thought of as the loose material covering the dry surface of the earth, but it is much more than that. To become soil, this material must be acted on by the soil forming factors: time, biota, topography, climate, and parent material. These factors produce a series of horizons in the soil that make it distinct from simply ground-up rock. Simply observing a dark-colored surface layer overlying a reddish lower layer shows that changes in the original parent material have taken place. The many organisms growing in and on soil, including large, small, and microscopic plants, animals, and microorganisms also differentiate soil from ground-up rock.

There are other less obvious physical changes constantly taking place in soil. Soil temperature changes dramatically from day to night, week to week, and season to season. Even in climates where the air temperature is relatively constant, soil temperatures can vary by 20 degrees or more from day to night.

Moisture levels can change from saturation to air dry, which can be as low as 1% moisture on a dry-weight basis. These changes have dramatic effects on the chemical reactions in the soil. Changes in soil water content alter the concentration of soil constituents and thus also their reaction rates.

Not only are soil's physical and observable characteristics different from those of ground-up rock; so also are its chemical characteristics. Soil is a mixture of inorganic and organic solids, liquids, and gases. In these phases can be found inorganic and organic molecules, cations, and anions. Inorganic and organic components can be preset as simple or complex ions. Crystalline material occur having different combinations of components from, for example, 1:1 and 2:1 clay minerals, leading to different structures with different physical and chemical characteristics with different surface functionalities and chemical reactivities.

Organic components range from the simple gaseous compounds, such as methane, to very complex materials, such as humus. Included in this mix are gases, liquids, and solids, and hydrophobic and hydrophilic molecules and ions. All organic functional groups are included in soil organic matter, and it is common to find polyfunctional organic molecules as well as simple and complex biochemicals. Humus is an example of a complex molecule that contains many different functional groups. Polyfunctional organic molecules and biochemicals coordinate and chelate with inorganic materials in soils, particularly metals.

The fact that soil always contains water, or more precisely an aqueous solution, is extremely important to keep in mind when carrying out an analytical procedure involving soil because water can adversely affect analytical procedures and instrumentation. This can result in an over- or underdetermination of the concentrations of components of interest. Deactivation of chromatographic adsorbants and columns and the destruction of sampling tools such as salt windows used in infrared spectroscopy are examples of the deleterious effects of water. This can also result in absorbence or overlap of essential analytical bands in various regions of the spectrum.

All of these physical and chemical characteristics have a pronounced effect on soil and its analysis. The intention here is to first investigate some of the most important soil characteristics that impact its analysis and instrumentation applied to analysis of the soil as well as its extracts, and to elucidate those interferences that may be most troubling to the analysis.

Chapters conclude with a bibliography, followed by a list of references. The bibliography lists general sources for the material covered in the chapter, while the references give some specific examples illustrating the application to soil. These lists are intended to provide the reader with additional resources and examples of how the material covered in the chapter is actually used in soil analysis and research. They are also a source of standard methods and procedures of soil analysis and provide the reader with many analytical procedures along with pitfalls and interferences that may be encountered in the particular analysis being discussed.

The Internet references given have been checked and were found accurate at the time of writing. However, Internet addresses are subject to change. If you are unable to find an address, try accessing the parent organization and looking for the desired information through its home page. For instance, if the Internet address is a USDA (United States Department of Agriculture) site, you can access the USDA Web site and find the needed information from there.

The author wishes to thank D. Meinholtz, J. Bigham, N. Smeck, H. Skipper, B. Ramos, and T. Villamayer for their help in reviewing and preparing this manuscript.

ALFRED R. CONKLIN, JR.

CONTENTS

CHAPTER

1

SOIL BASICS I

MACROSCALE FEATURES

Soil is essential to life. All life supporting components derive, either directly or indirectly, from the soil. Plants growing in soil are directly used for food or are fed to animals, which are then used for food. These same plants take in carbon dioxide produced by animals and give off oxygen. Soil and the plants it supports moderate the amount of liquid and gaseous water in the environment by serving as a reservoir controlling its movement. Elements essential to life, even life in water, are released from soil solids and recycled by soil chemical and biologically mediated reactions.

Thus, although, as will be seen, soil is extremely complex, an understanding of its physical characteristics and the chemistry occurring in it are important in its analysis and the instruments used in this analysis.

Soil is vastly more complex than simply ground-up rock. It contains solid inorganic and organic components in various stages of decomposition and disintegration, an aqueous solution of elements, inorganic and organic ions and molecules, and a gaseous phase containing nitrogen, oxygen, carbon dioxide, water vapor, argon, and methane plus other gases. In addition, it contains a large and varied population of macro-, meso-, and microscale animals, plants, and microorganisms. If any of these components is missing, it is not soil!

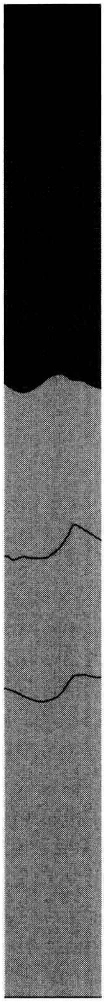
The solid portion of soil is composed of inorganic sand, silt, clay, and organic matter, which interact to produce the large soil features[1] (i.e., peds, profiles, pedons, landscapes). These features, not considering rock, are discussed in this chapter. In Chapter 2, components smaller than sand, which soil scientists define as those inorganic particles smaller than 2.00 mm in diameter, are discussed. Geologic features and gravel, stones, rock, and other substances are not discussed.

Large soil components consisting of sand, silt, clay, and organic matter are peds, profiles, pedons, and landscapes. Peds are formed by the aggregation of sand, silt, and clay particles to form larger (secondary) soil structures that result from the action of the soil forming factors (see Figures 1.1–1.5). Profiles develop in the loose material on the earth's surface and are composed of

[1] Many soils contain gravel, stones, and rock; however, these components, because of their low reactivity, will not be considered in this book.

Introduction to Soil Chemistry: Analysis and Instrumentation, By Alfred R. Conklin, Jr.

Alfisol



Oi 0 – 5 cm; undecomposed organic material, mainly bark, twigs, and needles.

Oe 5 –10 cm; partially decomposed organic material like that of the horizon above.

A 10 – 15 cm; dark gray (10YR 4/1) very stony loam, strong fine granular structure.

E 15 – 32.5 cm; pinkish gray (7.5YR 7/2) very stony very fine sandy loam, weak thick platy to strong fine granular structure.

E/B 32.5 – 45 cm; mixed pinkish gray (7.5YR 7/2) very stony loam, weak fine subangular structure.

Bt1 45 – 81 cm; brown (7.5YR 5/3) very stony clay, moderate fine subangular blocky structure.

Bt2 81 – 91 cm; brown (7.5YR 5/3) very stony clay loam, weak medium subangular blocky structure.

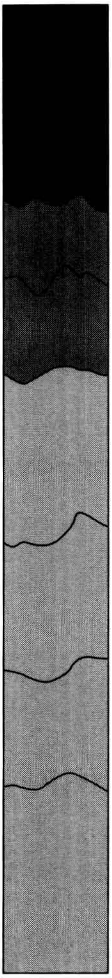
C 91 – 163 cm; brown (7.5 YR 5/4) extremely stony clay loam, massive.

Figure 1.1. An example of an Alfisol; this is the Seitz soil series, which is the state soil of Colorado (see Ref. 2).

horizons of varying texture, structure, color, bulk density, and other properties. Typically they are, as the name implies, horizontal, and are of varying thickness. A pedon is the smallest unit that can be considered "a soil" and consists of all horizons extending from the soil surface to the underlying geologic strata. An area consisting of similar pedons is called a *polypedon*.

Soil features, texture, peds, profiles, and other properties and materials go together in different ways to form different soils. Soil scientists in the United

Mollisol



Ap 0 – 17.5 cm; black (10YR 2/1) silty clay loam, weak fine granular structure.

A 17.5 – 35 cm; black (10YR 2/1) silty clay loam, moderate fine subangular blocky structure.

BA 35 – 48 cm; very dark gray (10YR 3/1) silty clay loam, moderate fine and medium subangular blocky structure.

Bg 48 – 64 cm; dark gray (10YR 4/1) silty clay loam, moderate fine prismatic to moderate fine angular blocky structure.

Btg1 64 – 81 cm; grayish brown (2.5Y 5/2) silty clay loam, weak fine and medium prismatic to moderate fine angular blocky structure.

Btg2 81 – 104 cm; gray (N 5/0) silty clay loam, weak medium prismatic to weak medium angular blocky structure.

2Btg3 104 – 119 cm; gray (N 5/0) loam , weak coarse subangular blocky structure.

2Cg 119 – 152 cm; dark gray (10YR 4/1) stratified loam and sandy loam, massive.

Figure 1.2. An example of a Mollisol; this is the Drummer soil series, which is the state soil of Illinois (see Ref. 2).

States classify soils into 12 orders. The orders are differentiated by their characteristics which are a result of the soil forming factors: climate, parent material, topography, biota, and time, which all interact during soil formation. Climate, moisture, and temperature, determine the biota, which can survive in the locality. However, topography and time will also determine the vegetation, as well as its age and whether it can survive in a certain locality. The soil parent