Contents

Part I Soil – Its Nature and Origin ................................................................. 1

1 The Origin of Soil ................................................................. 3
  1.1 Physical or Mechanical Weathering .................................................. 3
  1.2 Chemical Weathering – The Gate to Pedogenesis ............................... 3
  1.3 Weathering by Biological Agents ................................................... 5
    1.3.1 The Pedogenic Cycle – A Cycle within the
           Global Sedimentary Cycle ............................................. 6
    1.3.2 Transport Routes and Material Transfer within the Soil Body ........... 6
  1.4 Factors Controlling Soil Formation .............................................. 10
  1.5 Morphology of Soil ......................................................................... 11

2 Soil Constituents ................................................................. 15
  2.1 The Mineral Solid Phase ............................................................ 15
    2.1.1 The Orthosilicates .................................................................. 16
    2.1.2 Chain Silicates or Inosilicates .................................................. 17
    2.1.3 Sheet Silicates or Phyllosilicates ............................................. 18
    2.1.4 Framework Silicates or Tectosilicates ..................................... 23
  2.2 Organic Matter and Soil Organisms ........................................... 23
    2.2.1 Soil Organisms ..................................................................... 25
    2.2.2 Dead Organic Matter ............................................................ 28
  2.3 The Liquid Phase – Soil Water ..................................................... 42
    2.3.1 Composition of Soil Waters .................................................. 44
  2.4 The Gaseous Phase – Soil Air, Origin, Composition and Properties ...... 44

3 Soil Properties ................................................................. 47
  3.1 Physical Properties ............................................................... 47
    3.1.1 Colour ................................................................................. 47
    3.1.2 Texture ............................................................................... 47
    3.1.3 Structure ............................................................................ 47
    3.1.4 Consistence ......................................................................... 48
    3.1.5 Porosity ................................................................................ 49
  3.2 Chemical Properties ............................................................. 50
    3.2.1 Soil Acidity (pH) .................................................................. 50
    3.2.2 Ion Exchange ....................................................................... 51
3.2.3 Cation Exchange Capacity (CEC) .................................................. 52
3.2.4 The Interaction of Organic Soil Matter with Mineral Components ................................................. 53
3.2.5 Oxidation-Reduction Status .......................................................... 55

4 Soil Types and Classification .......................................................... 57
4.1 The Soil Taxonomy System – Criteria of Classification ....................... 57
4.1.1 Morphological Criteria of Classification in the Soil Taxonomy System (Diagnostic Horizons) .......... 57
4.1.2 Description of the Environmental Criteria of Classification ............. 60
4.1.3 Description of the Chemical Criteria of Classification .................. 62
4.1.4 Categories of the Taxonomy System Based on the Criteria of Classification ........................................... 63
4.1.5 The Soil Orders of Taxonomy ....................................................... 63
4.2 The FAO-UNESCO Soil Classification System ................................. 88
4.2.1 Description of the Reference Soil Groups of the World Reference Base for Soil Resources (WRB) .... 88
4.2.2 Relation Between the WRB System and the USDA Taxonomy System .................................................. 92
4.3 Other Systems of Classification ...................................................... 92
Examples of National Systems ........................................................... 93

5 Soil Degradation .............................................................................. 95
5.1 Soil Degradation and Soil Quality .................................................. 95
5.1.1 Biological Indicators of Soil Quality – Soil Respiration Rates ......... 95
5.1.2 Physical Indicators of Soil Quality ............................................... 96
5.1.3 Chemical Indicators of Soil Quality ............................................. 98
5.2 Physical Soil Degradation ............................................................ 100
5.2.1 Soil Erosion .............................................................................. 100
5.2.2 Soil Compaction .................................................................. 105
5.2.3 Soil Crusting and Sealing ......................................................... 108
5.3 Chemical Soil Degradation ......................................................... 110
5.3.1 Acidification .......................................................................... 110
5.3.2 Salinization and Sodicification ................................................. 112

Part II Soil Pollution ......................................................................... 115

6 Major Types of Soil Pollutants ....................................................... 117
6.1 Heavy Metals and Their Salts ....................................................... 117
6.1.1 Heavy Metals and the Soil System ........................................... 121
6.1.2 Transport of Heavy Metals within the Soil System ..................... 121
6.1.3 Bioavailability of Heavy Metals ............................................... 122
6.1.4 Biochemical Effects of Heavy Metals ...................................... 123
6.1.5 Major Environmental Accidents Involving Pollution by Heavy Metals .................................................. 124
### 6 Other Inorganic Pollutants
- Radionuclides
  - Speciation and Behaviour of Radionuclides in the Soil System
  - Uptake of Radionuclides by Plants
- Nuclear Debris from Weapon Tests and Belligerent Activities
- Nuclear Debris from Major Nuclear Accidents

### 7 Sources of Soil Pollution
- Pollutants of Agrochemical Sources
  - Insecticides
  - Herbicides
  - Fungicides
  - Fuel Spills in Farms
- Soil Pollutants of Urban Sources
  - Power Generation Emissions
  - Soil Pollution through Transport Activities
  - Soil Pollution by Waste and Sewage Sludge
- Soil Pollution through Chemical Warfare
  - Pollutants, Toxic Chemicals, and Chemical Weapons
  - Soil Pollution by Military Activities During the Cold War
- Soil Pollution through Biological Warfare (BW)
  - Bacteria
  - Viruses
  - Rickettsiae
  - Chlamydia
  - Fungi
  - Toxins

### 8 Pollution Mechanisms and Soil-Pollutants Interaction
- Physical Processes and Mechanisms of Pollution
  - Adsorptive Retention
  - Nonadsorptive Retention
- Contaminants Transport
  - Microscopic Dispersion: Molecular Diffusion
  - Macroscopic Dispersion
- Behaviour of Non-Aqueous Phase Liquids (NAPLs) in Soils
  - NAPLs Lighter than Water (LNAPLs)
  - NAPLs Denser than Water (DNAPLs)

### 9 Pollutants’ Alteration, Transformation, and Initiation of Chemical Changes within the Soil
- Processes Related to Chemical Mobility
  - Immiscible Phase Separation
  - Acid-Base Equilibrium
  - Dissolution-Precipitation Reactions
### Contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.2 Chemical Transformation Processes</td>
<td>202</td>
</tr>
<tr>
<td>9.2.1 Hydrolysis</td>
<td>206</td>
</tr>
<tr>
<td>9.3 Biodegradation and Biologically Supported Transformations</td>
<td>206</td>
</tr>
<tr>
<td>9.4 Enzymatic Transformations:</td>
<td></td>
</tr>
<tr>
<td>9.4.1 The Hydrolases</td>
<td>207</td>
</tr>
<tr>
<td>9.4.2 The Transferases</td>
<td>209</td>
</tr>
<tr>
<td>9.4.3 The Oxidoreductases</td>
<td>211</td>
</tr>
<tr>
<td>9.4.4 The Lyases</td>
<td>216</td>
</tr>
<tr>
<td>9.4.5 The Ligases</td>
<td>218</td>
</tr>
<tr>
<td>9.5 Transformations Assisted by Bacterial Action</td>
<td>219</td>
</tr>
<tr>
<td>9.5.1 Sulphur Bacteria</td>
<td>220</td>
</tr>
<tr>
<td>9.5.2 Nitrifying Bacteria</td>
<td>221</td>
</tr>
<tr>
<td>9.5.3 Iron Oxidising Bacteria</td>
<td>222</td>
</tr>
<tr>
<td>9.5.4 Methane Oxidising Bacteria</td>
<td>222</td>
</tr>
<tr>
<td>9.5.5 Hydrogen Bacteria</td>
<td>223</td>
</tr>
</tbody>
</table>

### Part III Monitoring of Soil Pollution

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Monitoring and Monitoring Plans</td>
<td>223</td>
</tr>
<tr>
<td>10.1 Site Characterisation</td>
<td>225</td>
</tr>
<tr>
<td>10.2 Data Acquisition</td>
<td>226</td>
</tr>
<tr>
<td>10.2.1 Sampling-Planning and Realisation</td>
<td>227</td>
</tr>
<tr>
<td>10.2.2 Sampling Procedures</td>
<td>228</td>
</tr>
<tr>
<td>10.3 Field and Laboratory Investigations</td>
<td>229</td>
</tr>
<tr>
<td>10.3.1 Investigation of Solid Matter</td>
<td>234</td>
</tr>
<tr>
<td>10.3.2 Investigation of Soil Solution</td>
<td>234</td>
</tr>
<tr>
<td>10.4 Monitoring of Groundwater Flows</td>
<td>235</td>
</tr>
<tr>
<td>10.4.1 The Different Zones of Groundwater</td>
<td>237</td>
</tr>
<tr>
<td>10.4.2 Monitoring Flow Directions</td>
<td>237</td>
</tr>
<tr>
<td>10.4.3 Monitoring Hydraulic Heads</td>
<td>238</td>
</tr>
<tr>
<td>10.4.4 Measuring Hydraulic Heads in the Vadose Zone</td>
<td>239</td>
</tr>
</tbody>
</table>

### Part IV Modelling of Soil Pollution

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 Models and Their Construction</td>
<td>245</td>
</tr>
<tr>
<td>12.1 Types of Models</td>
<td>247</td>
</tr>
<tr>
<td>12.1.1 Space Analogue Models</td>
<td>248</td>
</tr>
<tr>
<td>12.1.2 Mathematical Modelling of Fluid Flows in Soil</td>
<td>252</td>
</tr>
</tbody>
</table>
Part V  Soil Remediation ................................................................. 263

13  Planning and Realisation of Soil Remediation .............................. 265
13.1 Categories of Pollutants .......................................................... 265
13.2 Scale of Pollution ................................................................. 266
13.3 Risk Level .............................................................................. 267
13.4 Remediation Technologies ...................................................... 267
   13.4.1 Chemical and Physical Remedial Techniques ....................... 269
   13.4.2 Biological Treatment (Bioremediation) ............................... 273
   13.4.3 Solidification/Stabilisation Methods ................................. 279
   13.4.4 Thermal Treatment ......................................................... 280

References .................................................................................... 283

Index ............................................................................................. 301
Soil Pollution
Origin, Monitoring & Remediation
Mirsal, I.
2008, XV, 312 p., Hardcover
ISBN: 978-3-540-70775-2