

Table of contents

Preface	XV
List of authors	XVII
Acknowledgements	XXIII

Theme 1. Physico-chemistry of surfaces 1

CHAPITRE 1 : Introduction to the physical chemistry of surfaces ..	3
1.1. Generalities	3
1.2. Surface tension and wettability	4
1.2.1. <i>Concepts</i>	4
1.2.2. <i>Applications</i>	7
1.3. Adsorption	10
1.4. Charged surfaces	13
1.4.1. <i>Concepts</i>	13
1.4.2. <i>Interactions between charged surfaces</i>	16
1.5. Characterization and modification of surfaces	19
Acknowledgements	20
References	20

CHAPITRE 2 : Construction materials: general description and physical chemistry	21
2.1. General description – cements, mortars and concretes	21
2.1.1. <i>Portland cement</i>	22
2.1.2. <i>Calcium Aluminate Cements (CAC)</i>	25
2.1.3. <i>Modern cements: mixtures of minerals</i>	26
2.2. Setting and hardening – fundamental principles of crystallisation	27
2.2.1. <i>Notions of solubility equilibrium, undersaturation and supersaturation</i>	27

2.2.2.	<i>Nucleation</i>	30
2.2.3.	<i>Crystal growth</i>	32
2.2.4.	<i>Principles of crystallisation applied to Portland cement</i>	33
2.2.5.	<i>Principles of crystallisation applied to calcium aluminat cements</i>	36
2.3.	Surface chemistry of hydrated cements	38
2.3.1.	<i>Surface charge and ζ (zeta) potential</i>	38
2.3.2.	<i>Consequences for cementitious materials</i>	40
2.4.	Conclusion	40
	References	41
CHAPITRE 3 : Microorganism-Concrete Interactions		45
3.1.	General information	45
3.2.	Parameters influencing the bioreceptivity of cementitious materials	46
3.2.1.	<i>Relationship between these parameters and bioreceptivity</i>	47
3.2.2.	<i>Surface energy</i>	48
3.2.3.	<i>Measurement of contact angles</i>	49
3.3.	Measurements of the evolution of surface properties of cementitious pastes with the technique of measurement of dynamic angles	50
3.3.1.	<i>Implementation</i>	51
3.3.2.	<i>Evolution of contact angles as a function of time</i>	52
3.3.3.	<i>Evolution of contact angles as a function of diameter</i>	53
3.4.	Conclusion	58
	References	58

Theme 2. Biofilms: actors of biodeterioration 61

CHAPITRE 4 : The bacterial cell: the functional unit of biofilms		63
4.1.	Introduction	63
4.2.	Microorganisms	64
4.3.	Microbial diversity and habitat diversity	66
4.4.	Structures and functions of the bacterial cell	67
4.4.1.	<i>Cytoplasm, the nucleoid, and inclusions</i>	67
4.4.2.	<i>The cytoplasmic membrane</i>	68
4.4.3.	<i>Cell envelopes</i>	69
4.4.4.	<i>Appendages, filaments and cytoplasmic extensions</i>	72

4.5. Metabolism in bacteria 76

 4.5.1. *Aerobic respiration of chemoorganotrophs* 78

 4.5.2. *Aerobes chemolithotrophs* 79

 4.5.3. *The anaerobic respirations* 81

 4.5.4. *Fermentations* 85

 4.5.5. *Stratification and spatiometabolic structuration, syntrophy*. 86

 4.5.6. *Couplings of biotic and abiotic reactions: indirect biotic reactions* 89

4.6. Conclusion 90

References. 90

CHAPITRE 5 : Biofilm lifestyle of the microscopic inhabitants of surfaces 95

5.1. Biofilms, a lifestyle that concerns us 95

5.2. A continuous construction site 97

5.3. A complex organic cement to maintain the edifice 99

5.4. Nearly indestructible buildings. 102

 5.4.1. *The extracellular matrix as a protective shield* 102

 5.4.2. *Differentiation and physiological adaptation.* 104

 5.4.3. *The biofilm as a trigger of genetic plasticity in bacteria.* 105

 5.4.4. *Quorum-sensing, the social network of bacteria* 106

 5.4.5. *Multispecies biofilms: a successful alliance* 106

5.5. How to live with biofilms. 107

References. 108

CHAPITRE 6 : Journey to the centre of biofilms: nature, cohesiveness and functions of the exopolymer matrix 123

6.1. Chemistry of EPS in environmental biofilms 125

6.2. Contribution of EPS to the cohesiveness of biofilms 126

6.3. Reactivity of EPS in biofilms. 133

 6.3.1. *Trapping ions and organics by EPS* 133

 6.3.2. *Hydrolytic enzymes associated with EPS.* 134

 6.3.3. *Protection of biofilms against disinfectants* 134

6.4. Conclusion 135

References. 136

CHAPITRE 7 : Biofilms in a marine environment: example of intertidal mud flats and metallic port structures 143

7.1. Biofilm life of marine bacteria 143

7.2. Consequences of the establishment of biofilms on human activity in the marine environment. 144

7.3. Bacterial communities of two examples of marine biofilms that may have different impacts	146
7.3.1. <i>The biofilms of the intertidal mudflats</i>	148
7.3.2. <i>The biofilms of metallic port structures</i>	149
7.3.3. <i>Interactions within marine biofilms.</i>	153
7.4. Conclusion	154
References.	155
CHAPITRE 8 : Biofilms and management of microbial quality in drinking water supply systems.	161
8.1. From treatment plant to the tap: a vast, and complex to manage, chemical and biological reactor.	162
8.2. The water-material interfaces in drinking water distribution systems	164
8.3. Evolution of understanding of the causes for bacterial growth in drinking water distribution systems	165
8.3.1. <i>Biodegradable organic matters</i>	166
8.3.2. <i>Knowledge on biofilms</i>	168
8.4. Controlling biofilms in drinking water distribution systems	170
8.5. Conclusion	171
References.	172
CHAPITRE 9 : Biofilms in industrial cooling circuits	177
9.1. Introduction	177
9.2. Biofilm and evaporative cooling circuits: health hazard	178
9.2.1. <i>Evaporative cooling circuits</i>	178
9.2.2. <i>Characteristics of biofilms in the circuits</i>	180
9.2.3. <i>Detection and measurement of the biofilm</i>	182
9.2.4. <i>“Risk of Legionella” and the role of biofilm</i>	184
9.2.5. <i>Major health hazard factors</i>	185
9.2.6. <i>“Legionella risk” management strategy</i>	188
9.3. Biofilm in a refrigerated system: the risk of corrosion.	191
9.3.1. <i>Cold water piping system</i>	191
9.3.2. <i>Characteristics of biofilms in cold water piping systems.</i>	192
9.3.3. <i>Danger due to corrosion induced by microorganisms</i>	192
9.3.4. <i>Major risk factors.</i>	193
9.3.5. <i>Corrosion risk management strategy</i>	196
9.4. Conclusion	197
References.	198

Theme 3. Biocorrosion of metallic materials	201
CHAPITRE 10 : Electrochemical methods applied to biocorrosion	203
10.1. Introduction	203
10.2. Influence of EPS obtained from <i>Pseudomonas</i> sp. NCIMB 2021 on the corrosion behaviour of 70Cu-30Ni alloy in sea water	204
10.2.1. <i>Experimental methods</i>	204
10.2.2. <i>Results: electrochemical measurements</i>	206
10.2.3. <i>Corrosion mechanism</i>	208
10.2.4. <i>Impedance model</i>	209
10.2.5. <i>Results: corrosion current</i>	213
10.3. Influence of EPS extracted from <i>Desulfovibrio alaskensis</i> on the corrosion behaviour of carbon steel St37-2 in sea water	213
10.3.1. <i>Experimental results</i>	214
10.3.2. <i>Results</i>	215
10.4. Conclusion	216
Acknowledgments	217
References	217
CHAPITRE 11 : On the iron-sulphur interactions involved in biocorrosion phenomena	221
11.1. Introduction	221
11.2. Marine corrosion of carbon steel	222
11.2.1. <i>Role of the corrosion product layer</i>	223
11.2.2. <i>Description of the corrosion product layer</i>	224
11.3. Corrosion of carbon steel in argillite and corrosion cells associated with heterogeneous corrosion product layers	228
11.3.1. <i>Heterogeneity of the corrosion product layer</i>	228
11.3.2. <i>Galvanic cells and heterogeneity of the corrosion product layer</i>	230
11.4. Conclusion	233
References	234

Theme 4. Biodeterioration of non-metallic materials 239

CHAPITRE 12 : Biodeterioration of cementitious materials: interactions environment - microorganisms - materials	241
12.1. Introduction	241
12.2. Interactions between the environment and microorganisms	242
12.2.1. <i>Algae and cyanobacteria</i>	<i>242</i>
12.2.2. <i>Fungi</i>	<i>243</i>
12.2.3. <i>Bacteria.</i>	<i>244</i>
12.3. Interactions between the environment and cementitious materials	245
12.3.1. <i>Ageing of cementitious materials according to the environment</i>	<i>245</i>
12.3.2. <i>Bicolonization of cementitious materials</i>	<i>248</i>
12.4. Interactions between the environment and cementitious materials: biodeterioration	251
12.4.1. <i>Aesthetic biodeterioration</i>	<i>251</i>
12.4.2. <i>Mechanical biodeterioration</i>	<i>251</i>
12.4.3. <i>Chemical / mechanical biodeterioration.</i>	<i>252</i>
12.5. Scientific approach to study the biodeterioration of cementitious materials	255
12.5.1. <i>Laboratory tests for aesthetic biodeterioration</i>	<i>256</i>
12.5.2. <i>Laboratory tests for the chemical/mechanical biodeterioration</i>	<i>257</i>
12.6. Conclusion	260
References.	263

CHAPITRE 13 : Concrete biodeterioration	269
13.1. Introduction	269
13.2. Material biodeterioration, specificities of concrete	269
13.2.1. <i>Chemical specificity</i>	<i>270</i>
13.2.2. <i>Physics specificities</i>	<i>271</i>
13.2.3. <i>Specificity of the study of the actual biodeterioration of concrete</i>	<i>273</i>
13.3. Generic biodeterioration process.	273
13.4. Measurement of concrete biodeterioration.	277
13.4.1. <i>Physical Properties</i>	<i>277</i>
13.4.2. <i>Chemical properties</i>	<i>278</i>

13.5. Improvement of concrete strength.	278
13.5.1. <i>Concrete composition</i>	278
13.5.2. <i>Implementation</i>	279
13.6. Differences between chemical attack and biological attack	281
13.7. Conclusion	282
References.	283
CHAPITRE 14 : Biodeterioration of cementitious materials	
in sewage structures	287
14.1. Introduction	287
14.2. How does biodeterioration manifest itself in sewage	
and wastewater structures?	289
14.3. Hydrogen sulphide: the main vector of biodeterioration	
phenomenon in sewage structures	292
14.4. Impact of biodeterioration on cement materials.	295
14.4.1. <i>Influence of the chemical composition of the cement material</i>	
<i>on its durability in sewage systems</i>	296
14.4.2. <i>Polymer coatings as protection for cement materials in sewage</i>	
<i>and wastewater systems</i>	300
14.5. Tests <i>in situ</i> for the study of the biodeterioration phenomenon	
in sewage and wastewater systems	301
14.5.1. <i>Exposure in South Africa, the Virginia Experimental Sewer</i> . . .	301
14.5.2. <i>Exposure in Japan, Hokkaido university.</i>	302
14.5.3. <i>Exposure in France, Ifsttar</i>	303
14.6. Conclusion	304
References.	305
CHAPITRE 15 : Biodeterioration of cultural properties.	309
15.1. Introduction	309
15.2. Microorganisms involved in the biodeterioration of cultural	
property	310
15.2.1. <i>Microscopic fungi.</i>	310
15.2.2. <i>Basidiomycetes</i>	312
15.2.3. <i>Non-photosynthetic bacteria</i>	315
15.2.4. <i>Photosynthetic microorganisms</i>	316
15.3. Fungi detection methods.	319
15.4. Manganese oxidation of medieval stained glass windows.	320
15.5. Treatments methods: the use of UV-C radiation.	322
15.6. Conclusion	325
References.	325

Theme 5. Design and modification of materials 329

CHAPITRE 16 : Choosing metallic materials with respect to microbial induced corrosion.....	331
16.1. Introduction.....	331
16.2. Titanium and its alloys.....	333
16.3. Aluminium and its alloys.....	334
16.4. Non-alloy steels.....	335
16.4.1. <i>Pitting factor.....</i>	<i>336</i>
16.4.2. <i>Quantification of general corrosion in natural water.....</i>	<i>339</i>
16.5. Stainless steels.....	343
16.5.1. <i>Aerated environments.....</i>	<i>344</i>
16.5.2. <i>Deaerated environments.....</i>	<i>345</i>
16.5.3. <i>Mixed environments (with aerated and deaerated zones).....</i>	<i>347</i>
16.6. Conclusion.....	349
References.....	350

CHAPITRE 17 : Antimicrobial surfaces: A tool to combat biofilm development.....	353
17.1. Introduction.....	353
17.2. Different types of antimicrobial surfaces or coatings.....	354
17.2.1. <i>Nanostructured surfaces.....</i>	<i>354</i>
17.2.2. <i>Antimicrobial peptides.....</i>	<i>356</i>
17.2.3. <i>Polymer with anti-adhesive property: polyethylene glycol.....</i>	<i>359</i>
17.2.4. <i>Coating containing nanoparticles (Ag, Cu, TiO₂, ZnO, CuO).....</i>	<i>359</i>
17.2.5. <i>Biocidal polymers (hydrophobic cationic polymers, N-halamines).....</i>	<i>361</i>
17.3. Focus on N-halamine coatings (regenerable).....	362
17.4. Conclusion.....	370
References.....	370

CHAPITRE 18 : Extracellular microbial substances for cementitious materials.....	375
18.1. Introduction: cementitious materials and admixtures.....	375

18.2. Extracellular microbial substances 376

18.3. Influence of the EPSs on mechanical performances 377

 18.3.1. *Rheological properties* 377

 18.3.2. *Compressive strength* 379

18.4. Influence of EPS on physicochemical characteristics 380

 18.4.1. *Porosity* 380

 18.4.2. *Mechanisms of hydration* 382

 18.4.3. *Roughness of cement pastes* 384

**18.5. Interaction between extracellular substances
and cementitious materials: curative actions** 386

 18.5.1. *Self-healing concrete* 386

 18.5.2. *Permeability of cementitious materials* 387

18.6. Conclusion 387

References 388