



Biological Wastewater Treatment in Warm Climate Regions

Marcos von Sperling and
Carlos Augusto de Lemos Chernicharo

Volume Two

Published by IWA Publishing, Alliance House, 12 Caxton Street, London SW1H 0QS, UK

Telephone: +44 (0) 20 7654 5500; Fax: +44 (0) 20 7654 5555; Email: publications@iwap.co.uk
Website: www.iwapublishing.com

First published 2005

© 2005 IWA Publishing

Copy-edited and typeset by TechBooks, India

Printed by TJ International, Padstow, UK

Apart from any fair dealing for the purposes of research or private study, or criticism or review, as permitted under the UK Copyright, Designs and Patents Act (1998), no part of this publication may be reproduced, stored or transmitted in any form or by any means, without the prior permission in writing of the publisher, or, in the case of photographic reproduction, in accordance with the terms of licences issued by the Copyright Licensing Agency in the UK, or in accordance with the terms of licenses issued by the appropriate reproduction rights organization outside the UK. Enquiries concerning reproduction outside the terms stated here should be sent to IWA Publishing at the address printed above.

The publisher makes no representation, expressed or implied, with regard to the accuracy of the information contained in this book and cannot accept any legal responsibility or liability for errors or omissions that may be made.

Disclaimer

The information provided and the opinions given in this publication are not necessarily those of IWA or of the editors, and should not be acted upon without independent consideration and professional advice. IWA and the editors will not accept responsibility for any loss or damage suffered by any person acting or refraining from acting upon any material contained in this publication.

British Library Cataloguing in Publication Data

A CIP catalogue record for this book is available from the British Library

Library of Congress Cataloguing-in-Publication Data

A catalogue record for this book is available from the Library of Congress

ISBN: 1 84339 002 7; 1 84339 107 4 (this volume)

Contents

Volume Two

PART FIVE ACTIVATED SLUDGE

30	Activated sludge process and main variants	839
30.1	Introduction	839
30.2	Variants of the activated sludge process	842
31	Principles of organic matter removal in continuous-flow activated sludge systems	855
31.1	Preliminaries	855
31.2	Sludge age in activated sludge systems	857
31.3	Suspended solids concentration in the reactor	857
31.4	Calculation of the reactor volume	859
31.5	Substrate removal	862
31.6	Soluble BOD and total BOD in the effluent	865
31.7	Sludge digestion in the reactor	869
31.8	Recirculation of the activated sludge	872
31.9	Production and removal of excess sludge	877
31.10	Oxygen requirements	886
31.11	Nutrient requirements	893
31.12	Influence of the temperature	896
31.13	Functional relations with the sludge age	897
32	Design of continuous-flow activated sludge reactors for organic matter removal	906
32.1	Selection of the sludge age	906
32.2	Design parameters	908
32.3	Physical configuration of the reactor	909

33	Design of activated sludge sedimentation tanks	915
33.1	Types of sedimentation tanks	915
33.2	Determination of the surface area required for secondary sedimentation tanks	916
33.3	Design details in secondary sedimentation tanks	937
33.4	Design of primary sedimentation tanks	939
34	Design example of an activated sludge system for organic matter removal	942
34.1	Introduction	942
34.2	Model parameters and coefficients	943
34.3	Design of the conventional activated sludge system	944
34.4	Summary of the design	957
35	Principles of biological nutrient removal	959
35.1	Introduction	959
35.2	Nitrogen in raw sewage and main transformations in the treatment process	961
35.3	Principles of nitrification	965
35.4	Principles of biological denitrification	978
35.5	Principles of biological phosphorus removal	986
36	Design of continuous-flow systems for biological nutrient removal	997
36.1	Biological nitrogen removal	997
36.2	Biological removal of nitrogen and phosphorus	1015
37	Intermittent operation systems (sequencing batch reactors)	1023
37.1	Introduction	1023
37.2	Principles of the process	1023
37.3	Process variants	1026
37.4	Design criteria for sequencing batch reactors	1031
37.5	Design methodology for sequencing batch reactors	1034
37.6	Design example of a sequencing batch reactor	1035
38	Activated sludge for the post-treatment of the effluents from anaerobic reactors	1042
38.1	Design criteria and parameters	1042
38.2	Design example of an activated sludge system for the post-treatment of the effluent from a UASB reactor	1045
39	Biological selectors	1055
39.1	Introduction	1055
39.2	Types of selectors	1057
40	Process control	1061
40.1	Introduction	1061
40.2	Basic concepts of process control	1063

40.3	Dissolved oxygen control	1065
40.4	Solids control	1066
40.5	Monitoring the system	1073
41	Identification and correction of operational problems	1074
41.1	Introduction	1074
41.2	High concentrations of suspended solids in the effluent	1075
41.3	High BOD concentrations in the effluent	1098
41.4	High ammonia concentrations in the effluent	1103
 PART SIX AEROBIC BIOFILM REACTORS		
42	Basic principles of aerobic biofilm reactors <i>R.F. Gonçalves</i>	1113
42.1	Introduction	1113
42.2	Classification of aerobic biofilm reactors	1114
42.3	Formation, structure and behaviour of biofilms	1115
43	Trickling filters <i>C.A.L. Chernicharo, R.F. Gonçalves</i>	1119
43.1	Description of the technology	1119
43.2	Design criteria	1123
43.3	Construction aspects	1130
43.4	Operational aspects	1131
44	Rotating biological contactors <i>R.F. Gonçalves</i>	1135
44.1	Introduction	1135
44.2	Description of the technology	1135
44.3	Design criteria	1137
44.4	Construction aspects and characteristics of the support medium	1140
45	Submerged aerated biofilters <i>R.F. Gonçalves</i>	1142
45.1	Introduction	1142
45.2	Description of the technology	1142
45.3	Design criteria	1150
45.4	Construction aspects	1152
45.5	Operational aspects	1153

PART SEVEN SLUDGE TREATMENT AND DISPOSAL

46	Introduction to sludge management <i>M. von Sperling, C.V. Andreoli</i>	1167
----	--	------

47	Sludge characteristics and production	1170
	<i>M. von Sperling, R.F. Gonçalves</i>	
47.1	Sludge production in wastewater treatment systems	1170
47.2	Sludge characteristics at each treatment stage	1172
47.3	Fundamental relationships in sludge	1178
47.4	Calculation of the sludge production	1182
47.5	Mass balance in sludge treatment	1194
48	Main contaminants in sludge	1197
	<i>S.M.C.P. da Silva, F. Fernandes, V.T. Soccol, D.M. Morita</i>	
48.1	Introduction	1197
48.2	Metals	1198
48.3	Trace organics	1205
48.4	Pathogenic organisms	1206
49	Sludge stabilisation	1214
	<i>M. Ludovice</i>	
49.1	Introduction	1214
49.2	Anaerobic digestion	1215
49.3	Aerobic digestion	1233
50	Sludge thickening and dewatering	1242
	<i>R.F. Gonçalves, M. Ludovice, M. von Sperling</i>	
50.1	Thickening and dewatering of primary and biological sludges	1242
50.2	Sludge thickening	1244
50.3	Sludge conditioning	1247
50.4	Overview on the performance of the dewatering processes	1256
50.5	Sludge drying beds	1257
50.6	Centrifuges	1265
50.7	Filter press	1273
50.8	Belt presses	1280
50.9	Thermal drying	1284
51	Pathogen removal from sludge	1286
	<i>M.T. Pinto</i>	
51.1	Introduction	1286
51.2	General principles	1287
51.3	Mechanisms to reduce pathogens	1289
51.4	Processes to reduce pathogens	1293
51.5	Operation and control	1310
52	Assessment of sludge treatment and disposal alternatives	1315
	<i>F. Fernandes, D.D. Lopes, C.V. Andreoli, S.M.C.P. da Silva</i>	
52.1	Introduction	1315
52.2	Sustainable point of view	1316
52.3	Trends in sludge management in some countries	1316

52.4	Aspects to be considered prior to the assessment of alternatives	1318
52.5	Criterion for selecting sludge treatment and final disposal alternatives	1321
52.6	Sludge management at the treatment plant	1326
53	Land application of sewage sludge	1328
	<i>C.V. Andreoli, E. S. Pegorini, F. Fernandes, H.F. dos Santos</i>	
53.1	Introduction	1328
53.2	Beneficial use	1329
53.3	Requirements and associated risks	1335
53.4	Handling and management	1343
53.5	Storage, transportation and application of biosolids	1352
53.6	Operational aspects of biosolid land application	1357
53.7	Landfarming	1367
54	Sludge transformation and disposal methods	1373
	<i>M. Luduvic, F. Fernandes</i>	
54.1	Introduction	1373
54.2	Thermal drying	1374
54.3	Wet air oxidation	1375
54.4	Incineration	1378
54.5	Landfill disposal	1381
55	Environmental impact assessment and monitoring of final sludge disposal	1392
	<i>A. I. de Lara, C.V. Andreoli, E.S. Pegorini</i>	
55.1	Introduction	1392
55.2	Potentially negative environmental impacts	1393
55.3	Monitoring indicators and parameters	1396
55.4	Monitoring plan	1398
	<i>Index</i>	1409