

**The Performance of
Facultative Waste Stabilisation Ponds
in the United Kingdom**

by

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Submitted in accordance with the requirements
for the degree of Doctor of Philosophy

The University of Leeds
School of Civil Engineering

September 2002

The candidate confirms that the work submitted is her own and that appropriate credit has been given where reference has been made to the work of others.

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for Andy Hackett

ACKNOWLEDGEMENTS

I would like to thank most sincerely all the people and organisations who helped me.

Thank you to the technical staff of the School of Civil Engineering. Marvin Wilman for practical help on site, Keith Pierre and Mick China for help in the lab. Peter Richards who turned a completely dead weather station into a fully operational device. Roy Trembath who came and surveyed my excavations with only a day's notice. John Howarth, Brian Tomlinson and Graham Grayson in the workshop for making various items for me, fixing others and donating their shelving for my shed. George Broadhead who wired my pumps for me. John Drake, who I could always turn to for help with ordering equipment and who supported me emotionally especially during the first year (which was a very tough time).

Thanks a million to the staff at Yorkshire Water. Tony Marks who allowed me to construct the pilot-plant, found me the site and gave me £10,000. Without Tony, this PhD would not be. Thank you to the staff on-site: Richard and Chris who were always around, made me feel very welcome and cheerfully helped me; Paul Blackburn (Blackie), who was always cheerful even after I bothered him numerous times for things. To Steve Grant who helped me with the weather station and Sarah Coleman, my contact, who was always supportive and helped wherever she could.

Thank you to Anglian Water for supporting the project financially and to Suzy Morton who always took the trouble to read my reports and comment, and always showed loads of interest in the project.

I would like to thank all the members of the Water Association especially Andrew Joiner, Simon Charter, Rick Hudson and Mark Moodie. These people not only taught me lots

about waste stabilisation ponds in the UK, showed me their systems and gave me time and data, but also gave me much needed moral support during my studies.

I would like to thank GK Gadsby Ltd, Nottingham, (Ken, John and David) for excavating the ponds, teaching me about site engineering and generally having lots of fun. Thank you to Environmental Lining Systems, Leeds, for the liner.

I would like to thank the Mott MacDonald Charitable Trust and the University of Leeds for sponsoring my PhD and allowing me to sustain a comfortable standard of living for three years.

Thank you to the academic staff in the School of Civil Engineering who helped me, not just academically, but also with moral support during my work, especially John Barton and Clive Beggs.

I would like to thank my fellow students who helped me: Tim Darlow, Veronica Saramento, Karla Navarrete who were excellent companions and gave me very useful practical help.

I would like to say a special thank you to Michelle Johnson, who started on the project in April 2001 and has since then, helped me whenever I have needed it without question. Her companionship and practical support made the second and third year's work much more bearable than the first.

Thank you to my supervisor and dear friend, Duncan Mara. Thank you Duncan for believing in me when I didn't believe in myself, for knowing I could do it, when I was sure I couldn't, for supporting me and always tolerating me. Thank you for keeping me on track and setting me ridiculously high standards. Without you this PhD would not be what it is.

I would like to thank my colleagues at the University of Leeds who have encouraged me since I was a very young technician. Thank you to Mick China who was the first person who suggested I do some “further education” and told me I could do it. Thank you to the School of Civil Engineering who paid for most of my education and allowed me time to do it. Thank you to MSF trade union who taught me to be confident and to negotiate for what I need.

Thank you to all my wonderful family for all the unconditional love they have always given me.

Finally, I would like to thank, from the bottom of my heart, my beloved Andy who has given me so much these last 14 years, it would take another PhD to write it all.

ABSTRACT

Three pilot-scale facultative ponds were constructed at Esholt wastewater treatment works in Bradford, West Yorkshire, UK. The ponds were operated in parallel to test the effect of surface BOD loading on performance, the maintenance of facultative conditions and the accumulation of sludge. The loading range tested was 63-169 kg BOD/ha.d. The performance criteria were BOD, SS and ammonia removal. The criterion for facultative conditions was the presence of an algal population maintaining aerobic conditions at the pond surface. BOD removal was on average 91%, non-seasonal, and related to surface BOD loading. SS removal was 94% on average, not related to surface BOD loading, but strongly affected by algae entering the effluent during summer. Ammonia removal was related to surface loading when the range was 62-169 kg BOD/ha.d. At a range of 63-107 kg BOD/ha.d, ammonia removal was strongly influenced by season: 0-42% in winter and 47-87% in summer. Facultative conditions, for which a criterion of $>300 \mu\text{g/l}$ chlorophyll-a was used, were not maintained during the winter at any of the test loadings (63-169 kg/ha d). At a surface loading of 63 kg/ha.d, the pond appeared to recover during the spring at the same time as the pond loaded at 82 kg/ha.d, therefore the most appropriate surface BOD loading for UK climatic conditions was asserted to be around 80 kg/ha.d, much lower than that required to optimise BOD and SS removal. At a loading of 80 kg/ha.d, the pond produced an effluent quality that met the EC Urban Waste Water Treatment Directive (1991) standard of $<25 \text{ mg filtered BOD /l}$ and $<150 \text{ mg SS/l}$ at all times. Nuisance factors encountered were: odour, mosquito breeding and duckweed. Anaerobic conditions were observed during the winter at loadings of $> 100 \text{ kg/ha.d}$ and briefly at a loading of 80 kg/ha.d after the ice melted. Mosquito breeding occurred in the pond loaded at 63 kg/ha.d during most of the summer; this pond was more shaded by trees and subject to fallen leaves than the other two. Duckweed was a serious problem during the first summer, and was removed manually thereafter. The accumulation of sludge, during the period July 2000 to March 2002, was 10-20% of the volume of the incoming settleable solids, equivalent to a rate of 0.09-0.22 $\text{m}^3/\text{person/yr}$. The predicted desludging interval for the ponds was between 7-10 years.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
ABSTRACT	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	xii
LIST OF FIGURES	xiv
ABBREVIATIONS AND SYMBOLS USED	xvii
1 INTRODUCTION	1
1.1 Sewage treatment in the UK	1
1.2 European legislation	2
1.3 Small sewage works and non-sewered discharges	3
1.4 The problem of sludge	4
1.5 Waste stabilisation pond use in the UK	5
1.6 The thesis	7
2 LITERATURE REVIEW	9
PART I: Waste Stabilisation Ponds	
2.1 Introduction	9
2.1.1 Terminology	10
2.2 Anaerobic ponds	10
2.3 Maturation (Aerobic) ponds	11
2.4 Facultative ponds	12
2.4.1 Introduction	12
2.4.2 Physical design	12
2.4.3 Facultative pond process biology	13
2.4.3.1 Algae	14
2.4.3.2 Bacteria	15
2.4.4 Aerobic and anaerobic conditions	16
2.4.5 Pond failure	18
2.4.6 Sludge accumulation	20
2.4.7 BOD removal	23
2.4.8 Suspended solids removal	24
2.4.8.1 Algal suspended solids	25
2.4.8.2 Removal of algae from effluents	26
2.4.9 Ammonia removal	27
2.4.9.1 Ammonia volatilisation	28
2.4.9.2 Ammonia assimilation	29
2.4.9.3 Biological nitrification	30
2.4.9.4 Ammonia removal efficiency	31
2.5 Facultative pond design theory	32
2.5.1 Design models	33
2.5.2 Hermann and Gloyna	33
2.5.3 The Gloyna equation	33
2.5.4 Marais and Shaw (Complete mix) model	35
2.5.5 Plug flow	37

2.5.6	Dispersed flow	38
2.6	Surface BOD loading	39
2.6.1	McGarry and Pescod empirical procedure	40
2.6.2	McGarry and Pescod: Envelope of failure	40
2.6.3	Surface loading: derivatives of McGarry and Pescod	41
2.6.4	Indian empirical procedure	42
2.6.5	Surface loading method: Interpretation of local data	42
PART II:		
Waste Stabilisation Pond Experience in Temperate Regions		
2.7	Introduction	44
2.8	United States	44
2.9	New Zealand	45
2.10	France	46
2.11	Germany	47
2.12	Belgium	48
2.13	Denmark	48
2.14	Summary	49
PART III Waste Stabilisation Ponds in the United Kingdom		
2.15	Introduction	50
2.16	Rye Mead maturation pond system	50
2.17	Burwarton Estate waste stabilisation pond system	51
2.18	Sturts Farm pond system	52
2.19	Wick St Lawrence (aerated lagoons)	53
2.20	Errol lagoons	53
2.21	Summary	54
2.22	UK temperature	54
2.23	Application of surface loading data and models to UK conditions	54
2.24	Conclusion	55
3	STUDY OF WASTE STABILISATION POND SYSTEMS IN THE UK	56
3.1	Introduction	56
3.2	Design criteria	56
3.3	Aeration and assistance systems	59
3.4	Physical design	60
3.5	Pond performance	61
3.5.1	Westfield Farm (Kent)	61
3.5.2	Halewell (Gloucestershire)	63
3.5.3	Spring Cottage (Wiltshire)	63
3.5.4	Botton Village (North Yorkshire)	64
3.5.5	Larchfield (Middlesborough)	65
3.5.6	The Tigh Mor Trossachs system (Stirling, Central Scotland)	69
3.6	Summary	70

4	PILOT-SCALE FACULTATIVE PONDS	71
	MATERIALS AND METHODS	
4.1	Construction of the pilot-scale facultative ponds	71
4.2	Measurement of surface area and volume	76
4.3	Pilot-scale system operation	76
4.4	Loading regime and influent characteristics	77
4.5	Site sampling and data collection	79
4.5.1	Weather data	79
4.5.2	Flow	79
4.5.3	Water temperature	80
4.5.4	Depth profile	80
4.5.5	Influent samples	81
4.5.6	Effluent and column samples	81
4.5.7	Sludge depth	82
4.6	Laboratory methods	83
4.6.1	Settleable solids	83
4.6.2	Suspended solids	83
4.6.3	BOD ₅	83
4.6.4	Chlorophyll-a	84
4.6.5	Ammonia	84
4.6.6	Microscopic examination	84
4.6.7	Chemical oxygen demand	84
4.6.8	Nitrate and nitrite	85
4.6.9	Total and volatile solids	85
4.6.10	Faecal coliforms	85
5	RESULTS	86
5.1	Climatic conditions at Esholt	86
5.1.1	Temperature of the ponds	86
5.2	BOD removal	89
5.2.1	The components of influent BOD to the pilot-scale facultative ponds	89
5.2.2	Unfiltered BOD removal and effluent quality	89
5.2.3	Filtered BOD removal and effluent quality	93
5.2.4	BOD load removal	95
5.2.5	The effect of hydraulic retention time on BOD removal	96
5.2.6	BOD removal: comparison with McGarry and Pescod (1970)	97
5.2.7	BOD removal: comparison with Marais and Shaw (1961)	99
5.3	Suspended solids removal	100
5.4	Ammonia removal	102
5.4.1	Ammonia removal: the effect of surface BOD load	104
5.4.2	Ammonia removal: the effect of year of operation and season	106
5.4.3	Ammonia removal: key parameters	110
5.4.4	Ammonia removal: comparison with Pano and Middlebrooks (1982)	112
5.4.5	Ammonia removal by nitrification	114
5.5	Facultative conditions	114
5.5.1	The chlorophyll-a concentration	114
5.5.2	Dissolved oxygen concentration	117
5.5.3	Site observations	126
5.5.4	Changes in pond biology	128

5.5.4.1	Changes in biology: fluctuations of chlorophyll-a	132
5.5.5	The contribution of chlorophyll-a to the dissolved oxygen concentration	134
5.5.6	Failure: comparison with McGarry and Pescod's "Envelope of Failure" (1970)	137
5.5.7	Failure: comparison with Mara's global design equation (1987)	138
5.5.8	Pilot-pond failure and recovery thresholds	139
5.6	Sludge accumulation	141
5.6.1	Total sludge accumulation compared to theoretical	145
5.6.2	Desludging interval	146
5.6.3	Sludge degradation	148
5.6.4	Faecal coliforms in sludge	150
6	DISCUSSION OF RESULTS	151
6.1	Influent composition	151
6.2	The uncertainty of the surface loading	153
6.3	BOD removal	153
6.4	Suspended solids removal	156
6.5	Ammonia removal	157
6.6	Facultative conditions	160
6.7	Sludge accumulation	162
6.8	The relative position of the ponds	164
6.9	Application issues	165
6.10	Mosquito breeding	167
6.11	Duckweed	168
6.12	Optimising facultative ponds in the UK	168
7	CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER WORK	170
7.1	Conclusions	170
7.2	Further work	171
	APPENDIX A Influent Characteristics	173
A1	The BOD concentration	173
A2	The suspended solids concentration	175
A3	The ammonia concentration	178
A4	The filtered BOD concentration and the supernatant BOD concentration	180
A5	The supernatant SS concentration	180
	APPENDIX B Duckweed	181
	APPENDIX C Pond Biology	186
C1	Algae	186
C2	Purple bacteria	189
C3	Other organisms	189

	APPENDIX D Sludge statistics	193
D1	Settleable solids concentration in the influent	193
D2	Estimation of the theoretical sludge volume	193
D3	Calculation of actual sludge accumulation volume	195
D4	Calculation of the contribution per person per year	195
D5	Percentage of volatile solids to total solids in the influent settleable solids	196
	APPENDIX E Temperature data	198
	LIST OF REFERENCES	203

LIST OF TABLES

		Page
Table 2.1	Some synonyms highlighting the different use of terminology	10
Table 2.2	The depth of ponds as suggested by Gloyna	35
Table 2.3	k_p 20 values for different surface loadings	38
Table 2.4	Facultative pond loading conversion	43
Table 2.5	Summary of pond surface BOD loading as recommended by the United States EPA manual	45
Table 2.6	Waste stabilisation ponds in the UK	51
Table 2.7	Possible surface loading values for the UK	55
Table 3.1	Summary of Waste Stabilisation Pond Systems in the UK by Consultant	56
Table 3.2	Contribution of the flowform cascade to DO in the first pond	61
Table 3.3	The performance of the first ponds at three systems in the south of England	64
Table 3.4	The performance of the first pond at Botton Village during winter 1998/99	65
Table 3.5	Larchfield Wheelhouse System: effluent statistics for January 1994-December 1998.	66
Table 3.6	Larchfield Levenhouse System: effluent statistics for October 1996-December 1998.	68
Table 3.7	Effluent data from the Tigh Mor Trossachs System (Jan 98-Mar 2000).	69
Table 4.1	Pond dimensions	76
Table 4.2	The experimental phases from July 00- July 02	77
Table 4.3	The average hydraulic retention time during each phase	78
Table 4.4	Weather station sensors	79
Table 4.5	Comparison of BOD (mg /l) in the screened sewage line and the influent to the ponds	81
Table 5.1	The mean BOD effluent concentration (mg O ₂ /l) for each pond in each phase	90
Table 5.2	Fitted values of % BOD removal from equation 5.2 at various loadings and chlorophyll-a concentrations.	92
Table 5.3	The mean filtered effluent BOD concentration (mg O ₂ /l) for each pond in each phase	94
Table 5.4	The mean effluent SS concentration (mg /l) for each pond in each phase	100
Table 5.5	The mean ammonia removal efficiency (%) for each pond in each phase	104
Table 5.6	The dates of failure and recovery (as identified by column chlorophyll-a concentrations) from spring 2001 onwards.	115
Table 5.7	Observations of all the ponds: November 2000-May 2001	127
Table 5.8	Observations of all the ponds : November 2001-March 2002	127
Table 5.9	Site observations May-July 2001	135
Table 5.10	Site observations April-July 2002	135
Table 6.1	Comparison of typical wastewater parameters with the influent to the pilot-scale ponds	152
Table 6.2	The surface loading range as calculated from the 95% confidence interval for the mean BOD	153

Table A1	Summary statistics for inlet BOD (mg/l) to each pond	173
Table A2	Summary statistics for inlet SS (mg/l) to each pond	175
Table D1	Summary statistics of the settleable solids to all ponds	193
Table D2	Estimation of the total flow to the ponds up to each sludge sampling event	194
Table D3	Calculation of the theoretical sludge volume originating from the influent	194
Table D4	Calculation of the average number of people served by each pond over 20 months	196

LIST OF FIGURES

		Page
Figure 2.1	Diagrammatic representation of processes in a facultative pond	14
Figure 3.1	Waste stabilisation pond systems in the UK in October 2000	57
Figure 3.2	The flowform cascade to the facultative pond at Spring Cottage, Wiltshire.	59
Figure 3.3	The facultative pond at Botton Village, North Yorkshire	60
Figure 3.4	The facultative pond at Westfield Farm	62
Figure 3.5	The system at Halewell Hotel with the facultative pond in the foreground	62
Figure 3.6	The facultative pond at Spring Cottage .	63
Figure 3.7	Ponds 2 and 3 at the Botton Village system	65
Figure 3.8	The anaerobic pond at the Larchfield (Wheelhouse) system	67
Figure 3.9	The facultative pond at the Larchfield (Wheelhouse) system	67
Figure 3.10	The facultative pond at the Larchfield (Levenhouse) system	68
Figure 3.11	The Tigh Mor Trossachs system	70
Figure 4.1	An excavation before lining	72
Figure 4.2	Formation of the ponds and embankments	72
Figure 4.3	An excavation with the HDPE liner fitted	73
Figure 4.4	Inlet structure	74
Figure 4.5	The outlet structure	74
Figure 4.6	Layout of the pilot-plant	75
Figure 4.7	The pilot-scale facultative ponds after completion	75
Figure 4.8	Sampling locations for the sludge depth experiment	82
Figure 5.1	Monthly summaries of the weather data from the Esholt weather station and from the UK Met Office	87
Figure 5.2	The mid-depth temperature and the influent temperature for all ponds	88
Figure 5.3	The components of the influent BOD	89
Figure 5.4	Monthly effluent BOD concentration for all ponds	90
Figure 5.5	Scatterplot of average effluent BOD concentration against surface loading	91
Figure 5.6	Monthly BOD filtered effluent concentration	93
Figure 5.7	Average filtered effluent BOD concentration against surface loading	95
Figure 5.8	Average surface removal against surface loading (as McGarry and Pescod)	98
Figure 5.9	Modelling of pilot-pond data as Marais and Shaw	99
Figure 5.10	The monthly average SS concentration in the effluent (all ponds)	101
Figure 5.11	Relationship between chlorophyll-a and SS in the effluent	102
Figure 5.12	Ammonia concentration in the effluent all ponds	103
Figure 5.13	Ammonia concentration removal all ponds	103
Figure 5.14	Average ammonia removal (phase) against surface BOD load	105
Figure 5.14a	Ammonia removal against surface BOD load partitioned for phase	105
Figure 5.15	Boxplot of effluent ammonia concentration from all ponds; comparison of Years 1 and 2	106
Figure 5.16	A scatterplot of effluent concentration against ammonia loading partitioned for year	107

Figure 5.17	Monthly surface ammonia removal (both years) with overall mean line	108
Figure 5.18	The relationship between ammonia surface loading and effluent concentration in year 2 partitioned for season	109
Figure 5.19	The relationship between ammonia surface loading and effluent concentration in year 1 partitioned for season	109
Figure 5.20	The relationship between surface ammonia removal and pH	110
Figure 5.21	The relationship between surface ammonia removal and surface temperature	111
Figure 5.22	The relationship between surface ammonia removal and the chlorophyll-a concentration	111
Figure 5.23	The relationship between effluent ammonia concentration and the hydraulic retention time	112
Figure 5.24	Scatterplot of ammonia effluent concentration against Pano and Middlebrooks predicted value C_e for first year (all ponds; partitioned for season)	113
Figure 5.25	Scatterplot of ammonia effluent concentration against Pano and Middlebrooks predicted value C_e for second year (all ponds; partitioned for season)	113
Figure 5.26	Nitrate and ammonia effluent concentrations	114
Figure 5.27	The average monthly chlorophyll-a column concentration for each pond	116
Figure 5.28	Average monthly DO concentration at the surface all ponds	118
Figure 5.29	DO profiles for the Red pond (Nov 2000-Aug 2001)	120
Figure 5.30	DO profiles for the Red pond (Sept 2001-Jun 2002)	121
Figure 5.31	DO profiles for the Green pond (Nov 2000-Aug 2001)	122
Figure 5.32	DO profiles for the Green pond (Sept 2001-Jun 2002)	123
Figure 5.33	DO profiles for the Blue pond (Nov 2000-Aug 2001)	124
Figure 5.34	DO profiles for the Blue pond (Sept 2001-Jun 2002)	125
Figure 5.35	Dominant organisms found in the effluent samples from all ponds	129
Figure 5.36	Dominant organisms found in the column samples from all ponds	130
Figure 5.37	Observations of <i>Culex</i> sp. in the pond effluent	131
Figure 5.38	Fluctuations in chlorophyll-a with changes in solar radiation, predation and competition effects	133
Figure 5.39	Fluctuations in chlorophyll-a concentration with changes in air temperature	134
Figure 5.40	Relationship between the DO concentration at the pond surface and the column chlorophyll-a concentration	136
Figure 5.41	Comparison of pilot-scale ponds failure threshold with McGarry and Pescod's Envelope of Failure	137
Figure 5.42	Comparison of pilot-scale ponds failure threshold with Mara's global design equation	139
Figure 5.43	Temperature thresholds for failure and recovery of pilot-scale ponds	140
Figure 5.44	Solar radiation thresholds for failure and recovery of pilot-scale ponds	140
Figure 5.45	Sludge accumulation in the Red pond	142
Figure 5.46	Sludge accumulation in the Green pond	143
Figure 5.47	Sludge accumulation in the Blue pond	144
Figure 5.48	The actual volume of sludge for each pond and the theoretical volume estimated from influent settleable solids	145
Figure 5.49	Prediction of the desludging interval based on the accumulation around the inlet to 20 months' operation	146
Figure 5.50	Leaves accumulating around the inlet of the Red pond (winter 2001)	147

Figure 5.51	Sludge feedback bringing settled leaves back to the surface	148
Figure 5.52	Sludge degradation over time: average percentage VS to TS all ponds and influent settleable solids	149
Figure 5.53	Temperature of the sludge	149
Figure A1	The sample acf plot of the time series of BOD concentration in the inlet	174
Figure A2	Plots of BOD data in the inlet as fitted to a normal distribution	174
Figure A3	Fitted values after a \log_{10} transformation of the BOD data	175
Figure A4	The acf plot for the influent SS concentration over 2 years	176
Figure A5	Normal plot of all inlet SS concentration values	177
Figure A6	Fitted values after a \log_{10} transformation of the SS data	177
Figure A7	Monthly mean ammonia concentration in the influent	178
Figure A8	The acf plot of the ammonia concentration time-series	179
Figure A9	Fitted moving average filter for inlet ammonia concentration	179
Figure B1	Duckweed (<i>Lemna minor</i>) on the Red pond	181
Figure B2	Duckweed removal in November 2000	182
Figure B2a	“Trawler” net for the removal of duckweed	183
Figure B3	Duckweed on the surface of the Red pond just before removal	183
Figure B4	The surface of the Red pond immediately after removal of the duckweed	184
Figure C1	The dominant organisms identified in effluent samples	187
Figure C2	The dominant organisms identified in column samples	188
Figure C3	<i>Chlamydomonas</i> (x 200 BF) Green pond, 19 June 2001	189
Figure C4	<i>Euglena</i> (x 100 BF) Blue pond 19 June 2001	190
Figure C5	<i>Phacus</i> (x200 BF) Red pond, 9 July 2001	190
Figure C6	<i>Chromatium</i> (x 200 BF). Green pond, 3 July 2001	190
Figure C7	<i>Rhodospseudomonas</i> (x200 BF) Red pond, 12 June 2001	191
Figure C8	Rotifer (x 100 BF). Red pond. 19 June 2001	191
Figure C9	Mosquito larvae Red pond, July 2002	191
Figure C10	<i>Paramecium</i> (x 200 BF) Blue pond, 19 June 2001	192
Figure D1	The pond base showing the sludge height measuring locations	195
Figure D2	The percentage of volatile solids to total solids in the influent	197
Figure E1	Diurnal temperature profiles for 5 July 2001	199
Figure E2	Diurnal temperature profiles for 25 October 2001	200
Figure E3	Diurnal temperature profiles for 8 January 2002	201
Figure E4	Diurnal temperature profiles for 12 March 2002	202

ABBREVIATIONS AND SYMBOLS USED

A	pond area
acf	autocorrelation function
amm.N	ammonical nitrogen
ANOVA	analysis of variance
BF	bright field lens
BOD	biochemical oxygen demand (5 day)
BOD _{loadrem}	BOD load removal
C_e	effluent concentration
$C_{e(\text{filt})}$	filtered effluent concentration
C_{emax}	maximum BOD in primary cells to avoid anaerobic conditions
CFU	colony forming unit
chl-a	chlorophyll-a
cm	centimetres
C_o	influent concentration
CO ₂	carbon dioxide
COD	chemical oxygen demand
CPHERI	Central Public Health Engineering Research Institute
d	day
d	depth
D	dispersion number
DEFRA	Department for the environment, food and rural affairs
DO	dissolved oxygen
DWF	dry weather flow
EA	Environment Agency (for England and Wales)
EC	European Community
EC UWWTD	European Council Directive on Urban Waste Water Treatment
EU	European Union
f	algal toxicity factor
f'	sulphide or other direct chemical oxygen demand
FC	faecal coliform
ha	hectare
k_c	first order reaction rate
k_{c_T}	reaction rate at water temperature T
kg	kilograms
km	kilometres
k_p	plug flow first order reaction rate
k_{p_T}	plug flow first order reaction rate at temperature T
kW	kilowatt
L	latitude
l	litres

L_a	ultimate BOD influent
LAS	Lake Aid Systems International Ltd
log	logarithm to base 10
λ_s	surface BOD loading
m	metres
mg	milligrams
μg	micrograms
mm	millimetres
mV	millivolts
n	sample size
N	nitrogen
N_2	molecular nitrogen
NH_3	ammonia
NH_4^+	ammonium ion
$NH_3\text{-N}$	ammonical nitrogen
NRA	National Rivers Authority
NW	northwest
O_2	oxygen
$^{\circ}\text{N}$	degrees north
$^{\circ}\text{S}$	degrees south
p	significance probability at the 95% level of confidence
P	phosphorus
p.e.	population equivalent
Q	flow rate
R	hydraulic retention time
RBC	Rotating biological contactor
r_n	hydraulic retention time for each pond in a series of n ponds
s	seconds
SEPA	Scottish Environment Protection Agency
SS	suspended solids
T	Temperature
q	Arrhenius constant / temperature coefficient
TS	total solids
UK	United Kingdom
US	United States
US EPA	United States Environment Protection Agency
V	pond volume
v	fluid velocity
VS	volatile solids
W	watts
WSP	waste stabilisation pond/s
WEF	Water Environment Federation