TABLE OF CONTENTS

MEMBRANE BIOREACTORS (MBRs)

Page

OBJECTIVES vi

USES OF THIS MANUAL vii

INSTRUCTIONS TO PARTICIPANTS IN HOME-STUDY COURSE viii

SUMMARY OF PROCEDURE viii

WORDS xiii

ACRONYMS xviii

LESSON 1

1 MEMBRANE BIOREACTOR (MBR) OVERVIEW 1

1.0 What Is a Membrane Bioreactor (MBR)? 2

1.1 MBR Layouts 3

1.10 Sidestream Layout 4

1.11 Submerged Layout 4

1.2 MBR Technologies 4

1.3 MBR Advantages and Limitations 7

2 MBR FACILITIES 7

2.0 Headworks 7

2.1 Biological Nutrient Removal Basins 8

2.10 Anoxic Zone 8

2.11 Aeration Zone 8

2.2 Membrane Zone 9

2.3 Permeate 9

2.4 Disinfection 9

2.5 Solids Treatment 10

DISCUSSION AND REVIEW QUESTIONS 10

LESSON 2

3 OPERATION OF THE MBR PROCESS 11

3.0 Pretreatment 11

3.00 Hydraulic Loading 11

3.01 Influent Screening 11

3.02 Pretreatment for Fats, Oils, and Grease (FOG) 11

3.1 Biological Nutrient Removal 11
3.2 Membrane Clogging and Fouling 12
3.3 Cleaning 14
3.4 Foaming 14
3.5 F/M Ratio 15
3.6 Membrane Integrity 16
3.7 Biological Operation and System Failure 17
3.8 Process Control and Monitoring Guidelines 17
3.9 MBR Failure Modes 17
3.10 Laboratory Testing 17
3.11 Typical Effluent Quality 17
DISCUSSION AND REVIEW QUESTIONS 19
LESSON 3
4 PROCESS CONTROL 21
4.0 SCADA Systems 21
4.1 Controllers 21
4.2 Control Functions 21
4.3 Monitoring Functions 21
4.4 Data Logging Functions 22
4.5 Alarm Functions 22
4.6 Diagnostic Functions 22
4.7 Remote Telemetry Units 23
4.8 Operator Interfaces 23
5 MAINTENANCE 24
5.0 Computer Maintenance Management System (CMMS) 24
5.1 Scheduled Maintenance 24
5.2 Critical Assets 25
5.3 Failure Consequence Analysis 25
5.4 Troubleshooting 34
DISCUSSION AND REVIEW QUESTIONS 34
LESSON 4
6 MBR START-UP AND COMMISSIONING 37
6.0 Critical Elements 37
6.1 Start-Up Coordination 37
6.2 SCADA System Implementation 37
6.3 Equipment Verification 39
6.4 Laboratory Setup 39

6.5 Equipment and System Testing 39
6.50 Equipment Demonstration Testing 39
6.51 Plant Commissioning Testing 39
6.52 Process Commissioning Testing 40
6.6 Plant Operations Standards Development 40
6.7 O&M Staff Training 40
6.8 O&M Documentation (Operations Guide) 40
7 MBR PLANT SAFETY 41
8 ADDITIONAL READING 41
DISCUSSION AND REVIEW QUESTIONS 42
SUGGESTED ANSWERS 42
COMPREHENSIVE REVIEW QUESTIONS AND SUGGESTED ANSWERS 45
SUBJECT INDEX 53

SUBJECT INDEX

A

Advantages of MBRs, 7
Aeration zone, 8–9
Alarm functions of SCADA systems, 22
Alarms
  anoxic mixer failure, 35
  effluent pumps fail to start, 36
  effluent pump shut down, 35
  high level in process trains, 35
  influent pump fails to start, 35
  influent pump station fails to start, 36
  influent pump station high level, 35
  influent screen high level, 35
  low DO, 36
  low level in process trains, 35
  low pH on influent flow, 35
  membrane blower fails to start, 36
  permeate pump failure, 36
  process blower fails to start, 36
  RAS pump failure, 36
  train shut down, 36
Alkalinity, consumption of, 12
Ammonification, 8
Anoxic zone, 8
Assets, critical, 25

B

Backwashing, 11
Bardenpho process for biological nutrient removal, 8
Barriers to the use of recycled water, 1
Bar screens, 11
Biological nutrient removal, 8–9, 11–12
Brown foam and F/M ratio, 15, 16
Brush cleaning of screens, 11

C

Chemical clean-in-place method, 14
Chemicals for cleaning membranes, 14
Chemical wastestream from cleaning, 14
City of San Diego's Advanced Water Treatment Demonstration Plant, 1
Cleaning membranes, 14
Clogging, 12, 13
CMMS (computer maintenance management system), 24
Commissioning and start-up of MBRs, 37–41
Computer maintenance management system (CMMS), 24
Consequence of failure, 25–33
Control functions of SCADA systems, 21
Controllers, 21
Conventional activated sludge (CAS) process used by MBRs, 5
Coordination, start-up, 37
Cost-effectiveness of an MBR system, 24

D

Data logging functions of SCADA systems, 22
Denitrification, 8
  rates of, 12
Design features to reduce foaming, 16
Diagnostic functions of SCADA systems, 22–23
Disinfection, 9–10

E

Effluent quality, 17, 19
Effluent turbidity, permit requirement, 26
Endogenous denitrification, 8
Endogenous respiration, 8
Energy costs of MBRs, 7
Equipment and system testing, 39
Equipment demonstration testing, 39
Equipment verification, 39
Excessive foaming and its impact, 14
External layout MBRs, 3, 4
Extracellular polymeric substances (EPSs), 11, 14

F

Facilities, MBRs, 7–10
Failure, system, 17
Failure consequence analysis (FCA), 25–33
Failure modes, MBR, 17, 18
Fats, oils, and grease (FOG), pretreatment for, 11
Federal Communications Commission (FCC), 23
Filamentous bacteria, 12, 14
Filter papers, 16
F/M ratio, 15
Foaming, 14–16
FOG (fats, oils, and grease), pretreatment for, 11
Fouling, 12, 14

G

(NO LISTINGS)

H

Headworks, 7
HMIs (human machine interfaces), 23
Hydraulic loading, 11
Hydrolysis, 8

I

Influent screening, 11
Internal layout MBRs, 3, 4
International Electrotechnical Commission (IEC), 21
Inventory of spare parts, 24

J

(NO LISTINGS)

K

(NO LISTINGS)

L

Laboratory setup, 39
Laboratory testing, 17, 19
Layouts of MBRs, 3–4
Limitations of MBRs, 7

M

Maintenance cleaning, 14
Maintenance management, 24
Maintenance of MBRs
  assets, critical, 25
  CMMS (computer maintenance management system), 24
  consequence of failure, 25–33
  failure consequence analysis (FCA), 25–33
  scheduled maintenance, 24
  troubleshooting, 34, 35–36
Mechanical equipment list (MEL), 39
Membrane clogging and fouling, 12, 13, 14
Membrane integrity, 16
Membrane life, 24
Membrane permeability, 17
Membrane technology used by MBRs, 5
Membrane zone, 9
Mixed liquor recycle rate, 12
MLSS concentrations in MBRs, 17
MMIs (man-machine interfaces), 23
Modified Ludzack-Ettinger (MLE) designs for biological nutrient removal, 8
Monitoring functions of SCADA systems, 21
Monitoring guidelines, 17

N

Nitrification, 8
  rates of, 12
Nitrobacter bacteria, 8
Nitrosomonas bacteria, 8
Nocardia, 12

O

O&M (operation and maintenance) documentation, 40
O&M (operation and maintenance) staff, 37
  training of, 40
Operation of the MBR process
  biological nutrient removal, 11–12
  cleaning membranes, 14
  clogging, 12, 13
  effluent quality, 17, 19
  failure, system, 17
  failure modes, 17, 18
  F/M ratio, 15
  foaming, 14–16
  fouling, 12, 14
  laboratory testing, 17, 19
  membrane integrity, 16
  monitoring guidelines, 17
  pretreatment, 11
  process control guidelines, 17
Operations guide, 40
Operator checklists (OCLs), 40
Operator interfaces (OIs) for SCADA systems, 23
Overaeration, 12

P

Perforated-plate (circular opening) screens, 11
Permeate, 4, 9
Permit requirement
  effluent turbidity, 26
  high pH, 29
  low pH, 29
pH
  control of, 12
  permit requirement for, 29
Plant commissioning testing, 39
Plant operations standards development, 40
Plant safety, 41

PLCs (programmable logic controllers), 21
Pretreatment, 11
Preventive maintenance (PM) procedures, 40
Process commissioning testing, 40
Process control, 21–23
Process control guidelines, 17, 19
Process strategies, 16
Programmable logic controllers (PLCs), 21
Public perception of recycled water, 1

Q

(NO LISTINGS)

R

Ragging, 11, 13
Recovery cleaning, 14
Recycled water, barriers to the use of, 1
Recycle rate of mixed liquor, 8
Remote (or radio) telemetry units (RTUs) used by SCADA systems, 21, 23
Return activated sludge (RAS) rate, 12

S

Safety, 41
SCADA systems
  alarm functions, 22
  control functions, 21
  controllers, 21
  data logging functions, 22
  diagnostic functions, 22–23
  implementation, 37
  layout, 22
  monitoring functions, 21
  operator interfaces (OIs), 23
  programmable logic controllers (PLCs), 21
  remote (or radio) telemetry units (RTUs), 23
Scheduled maintenance, 24
Screening, influent, 11
Screen washing, 11
Shock loads, 5
Sidestream layout MBRs, 3, 4
Sludge bulking, 14
Solids retention times (SRTs), 17
Solids treatment, 10
Spare parts inventory, 24
Staff training, 40
Standard operating procedures (SOPs), 40
Start-up and commissioning of MBRs, 37–41
Start-up coordination, 37
Submerged layout MBRs, 3, 4
Surface fouling, 14
System failure, 17
System testing, 39

T

Technologies, MBR, 4
Temperature, 12
Testing during commissioning and start-up
  equipment and system, 39
  equipment demonstration, 39
  plant commissioning, 39
  process commissioning, 40
  system, 39
Training of staff, 40
Transmembrane pressures (TMPs), 16
Troubleshooting MBRs, 34, 35–36

V

VDTs (video display terminals), 23
VDUs (video display units), 23

W

Wastewater treatment process strategies, 16
Wedge-wire screens, 11
White foam and F/M ratio, 15

X

(NO LISTINGS)

Y

(NO LISTINGS)

Z

(NO LISTINGS)