Manual of Water Supply Practices

M62

Membrane Applications for Water Reuse

First Edition

American Water Works Association

Manual of Water Supply Practices

M62

Membrane Applications for Water Reuse

First Edition

American Water Works Association

Manual of Water Supply Practices—M62

Membrane Applications for Water Reuse

Disclaimer
The authors, contributors, editors, and publisher do not assume responsibility for the validity of the content or any consequences of its use. In no event will AWWA be liable for direct, indirect, special, incidental, or consequential damages arising out of the use of information presented in this book. In particular, AWWA will not be responsible for any costs, including, but not limited to, those incurred as a result of lost revenue. In no event shall AWWA's liability exceed the amount paid for the purchase of this book.

If you find errors in this manual, please email books@awwa.org. Possible errata will be posted at www.awwa.org/resources-tools/resource.development.groups/manuals-program.aspx.

Senior Managing Editor/Project Manager: Melissa Valentine
Cover art: Melanie Yamamoto
Production: Janice Benight
Manuals Specialist: Sue Bach

Library of Congress Cataloging-in-Publication Data

Names: Wong, Joseph, active 2018, author. | Alspach, Brent, author. | Chalmers, Bruce, author. | American Water Works Association, issuing body.
Title: M62 - Membrane applications for water reuse / by Joseph Wong, Brent Alspach, Bruce Chalmers.
Other titles: Membrane applications for water reuse
Description: First edition. | Denver, CO : American Water Works Association, [2018]
Identifiers: LCCN 2018008413 | ISBN 9781625762627
Subjects: LCSH: Water reuse. | Membranes (Technology)
Classification: LCC TD429 .W66 2018 | DDC 628.1/64--dc23
LC record available at https://lccn.loc.gov/2018008413

Printed in the United States of America

ISBN 978-1-62576-262-7 eISBN-13 978-1-61300-448-7

American Water Works Association

American Water Works Association
6666 West Quincy Avenue
Denver, CO 80235-3098
awwa.org

Contents

This page intentionally blank.

Figures

This page intentionally blank.

Tables

Acknowledgments

The AWWA Technical and Educational Council, the Water Quality and Technology Division, and the Membrane Processes committee gratefully acknowledge the contributions of the volunteers who drafted, edited, and provided the significant and critical commentary essential to the development of AWWA M62. The Technical Review Board members dedicated many hours in the final stages of preparation of this edition to ensure the overall technical quality, consistency, and accuracy of the manual.

Technical Review Board Members

Joseph Wong, Chair, Brown and Caldwell, Walnut Creek, Calif.
Brent Alspach, ARCADIS, Carlsbad, Calif.
Bruce Chalmers, CDM Smith, Irvine, Calif.
Dawn Flancher, AWWA Staff, Denver, Colo.
Judith Herschell, Herschell Environment, Pittsburgh, Penn.
Kenneth Mercer, AWWA Staff, Denver, Colo.

Authors of the First edition

*A special thank you to these volunteers who served as chapter coordinators.

*Joseph Wong,** Chair, Brown and Caldwell, Walnut Creek, Calif.
*Jorge Aguinaldo,** RWL Water, Tampa, Fla.
Rick Bond, Black & Veatch, Kansas City, Mo.
Thomas Broderick, Loudoun Water, Ashburn, Vir.
Charlie Cruz, Separation Processes Inc., Carlsbad, Calif.
Emily Davis, Separation Processes Inc., Carlsbad, Calif.
James (Jay) DeCarolis, Black & Veatch, San Marcos, Calif.
Andrew Findlay, MWH Australia, Manly West, Qld Australia
Val Frenkel, EKI, Erler & Kalinowski Inc., Burlingame, Calif.
*Silvana M. Ghiu,** Hazen and Sawyer, San Diego, Calif.
Wesley Harijanto, California State Polytechnic University, Pomona, Calif.
Turaj Hosseini, Separation Processes Inc., Carlsbad, Calif.
Gary L. Hunter, Black & Veatch, Kansas City, Mo.
Curtis Kiefer, CDM Smith, Fort Lauderdale, Fla.
Tom Knoell, Orange County Water District, Fountain Valley, Calif.
Edmund A. Kobylinski, Black & Veatch, Cary, N.C.
Natalie W. La, California State Polytechnic University, Pomona, Calif.
*Jim Lozier,** ch2m, Tempe, Ariz.
Robert McCandless, Brown and Caldwell, Phoenix, Ariz.
*Chandra Mysore,** JACOBS™, Atlanta, Ga.
Jeff Neemann, Black & Veatch Corp., Kansas City, Mo.

Key Wee Ong, Singapore Public Utilities Board, Singapore
Eric Owens, West Basin Municipal Water District, Carson, Calif.
Mehul Patel, Orange County Water District, Fountain Valley, Calif.
Alan E. Rimer, Black & Veatch, Cary, N.C.
Cheryl Ross, West Basin Municipal Water District, Long Beach, Calif.
Larry Schimmoller, ch2m, Englewood, Colo.
Rich Stratton, HDR, Shingle Springs, Calif.
Arun Subramani, MWH, Arcadia, Calif.
Jennifer Thompson, CDM Smith, Carlsbad, Calif.
Ralph Valencia, United Water, Los Angeles, Calif.
*Don Vandertulip,** Arcadis, Dallas, Texas
*Vasu Veerapaneni,** Black & Veatch, Kansas City, Mo.
Alex Wesner, Separation Processes Inc., Carlsbad, Calif.
*Greg Wetterau,** CDM Smith, Rancho Cucamonga, Calif.
Wyatt Won, West Basin Municipal Water District, Carson, Calif.
Joe Zhao, URS Corporation, Santa Ana, Calif.
Christine Zheng, California State Polytechnic University, Pomona, Calif.

Reviewers to the First Edition

Robert Bergman, ch2m, Gainesville, Fla.
James Crook, Environmental Consultant, Norwell, Mass.

Chapter Authors

Chapter 1: Development of Water Reuse Practices

Don Vandertulip and Val Frenkel

Chapter 2: Planning for Reuse Applications

Don Vandertulip and Lisa Prieto

Chapter 3: Water Reuse Guidelines and Regulations

Joseph Wong and Cheryl Ross

Chapter 4: Source and Treated Water Quality

Chandra Mysore and Joseph Zhao

Chapter 5: Membrane Process Treatment Facility Design

Jorge T. Aguinaldo, James De Carolis, Srinivas Veerapaneni, Scott Freeman, Alex Wesner, Robert Bergman, Jeff Neemann, and James Lozier

Chapter 6: Operations

Silvana Ghiu, Eric Owens, Emily Davis, Turaj Hosseini, Ralph Valencia, Tom Knoell, and Wyatt Won

Chapter 7: Residuals Management

Chandra Mysore, Rick Bond, and Edmund Kobylinski

Chapter 8: Cost of Treatment

Greg Wetterau and Curt Kiefer

Chapter 9: Case Studies

Authors are listed in each case study

Chapter 10: Future Technology Trends and Contaminants of Emerging Concerns

Joseph Wong, Arun Subramani, and Robert McCandless

This page intentionally blank.

Preface

Reverse osmosis (RO) membranes have been used in water reuse since the 1960s. Cellulose acetate membranes for treating conventionally clarified municipal effluent was initially applied to small industrial applications and as irrigation water for golf courses. In the 1970s, Orange County Water District in southern California used cellulose acetate membranes to produce 5 mgd of RO permeate that was blended with imported water for injection into seawater intrusion barrier wells. The use of membranes in full-scale reuse applications has changed dramatically based on research performed in the 1980s and 1990s. Those efforts demonstrated that microfiltration–ultrafiltration (MF–UF) membranes can offer superior pretreatment compared to RO when treating municipal effluents. Those efforts also incorporated polyamide membrane, which has all but replaced cellulose acetate in this application.

In the 1990s, many municipal agencies began operating full-scale MF–UF and polyamide RO membrane systems to treat secondary and tertiary municipal effluents. At that time, early adopters of large-scale membrane treatment processes for water reuse were rare. These membrane users transitioned the industry from theoretical and pilot-scale investigations into full-scale operations, bringing about a new facet of water reuse. In the years since, the industry has learned much about membrane performance and sustainability over long-term operation, including handling unanticipated operational challenges brought on by organic-laden, variable feed sources that can change not only year to year but sometimes day to day.

Operational considerations for low- and high-pressure membrane technologies in water reuse applications are similar to their potable system analogs. However, there are subtle differences that can pose additional problems or issues to the water reuse operator if these are not considered or anticipated. Membrane system operators in reuse applications need to understand that "industry guidance" has historically been based on potable water treatment applications. Irreversible fouling and flux loss that lead to increased cleaning intervals and reduced membrane life are constant challenges in this environment. Finding the balance between cleaning frequency and chemical and energy costs is often the goal for membrane facilities in water reuse applications. Fiber breakage and loss of RO membrane rejection are significant problems that can be accelerated by this source water. This manual presents a comprehensive description of the issues related to applying membrane technologies in water reuse projects.

This page intentionally blank.

Abbreviations

ACH	aluminum chlorohydrate
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
AOC	assimilable organic carbon
AOP	advanced oxidation process
ASR	aquifer storage and recovery
AWT	advanced water treatment
AWWA	American Water Works Association
BAC	biologically active carbon
BIRM	biological immune response modulator
BNR	biological nutrient removal
BOD	biological oxygen demand
CA	cellulose acetate
$Ca(OCl)_2$	calcium hypochlorite
CEC	chemicals of emerging concern
CIP	clean in place
COC	cycles of concentration
COD	chemical oxygen demand
CTA	cellulose triacetate
DAF	dissolved air flotation
DALY	disability-adjusted life year
DOE	Department of Energy
DPR	direct potable reuse
EC	electrical conductivity
ED	electrodialysis
ED–EDR	electrodialysis–electrodialysis reversal
EDC	endocrine-disrupting chemical
EDR	electrodialysis reversal
efOM	effluent organic matter
ESA	Endangered Species Act
FAC	free available chlorine
FeCl3	ferric chloride
GRRP	groundwater recharge reuse projects
GWI	Global Water Intelligence
GWRRDR	Groundwater Replenishment Reuse Draft Regulation
HPM	high-pressure membrane
IMS	integrated membrane system

IPR	indirect potable reuse
LPM	low-pressure membrane
LRV	log-reduction value
MBR	membrane bioreactor
MCL	maximum contaminant limit
MF	microfiltration
MFI	modified fouling index
MGD	million gallons per day
MIC	microbiologically induced corrosion
MMFI	mini-plugging factor index
NaOCl	sodium hypochlorite
NDMA	*N*-nitrosodimethylamine
NF	nanofiltration
NOM	natural organic matter
NPDES	National Pollutant Discharge Elimination System
NTU	nephelometric turbidity unit
NWRI	National Water Research Institute
O&M	operations and maintenance
PA	polyamide
PAC	powdered activated carbon
PACl	polyaluminum chloride
PES	polyether sulfone
PP	polypropylene
PPCP	pharmaceuticals and personal care products
ppm	parts per million
PSU	polysulfone
PVDF	polyvinyl fluoride
RIB	rapid infiltration basins
RO	reverse osmosis
RWC	recycled water contribution
RWQCB	regional water quality control board
SAR	soil adsorption ratio
SAT	soil aquifer treatment
SBS	sodium bisulfite
SDI	silt density index
SMP	soluble microbial products
TCEQ	Texas Commission on Environmental Quality
TDC	total direct cell
TDS	total dissolved solids

TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
UF	ultrafiltration
USEPA	US Environmental Protection Agency
VOC	volatile organic compound
WHO	World Health Organization
WRA	WateReuse Association
WTP	water treatment plant
WWTP	wastewater treatment plant

This page intentionally blank.

Chapter 1

Development of Water Reuse Practices

HISTORY OF WATER REUSE

Reuse of water has occurred for centuries beginning with reuse of liquid waste in agricultural practice. Sewage farming was practiced in the United States in the 1800s and peaked in California in 1923, with 70 communities applying their municipal wastewater directly on food crops (NRC 2012). Agricultural water reuse was prominent in Texas south of San Antonio starting in the 1880s, with a formal contract between the City of San Antonio and the San Antonio Irrigation Company in 1901. Other Texas cities followed—Amarillo in 1920, Lubbock in 1930, Odessa in 1940, and Abilene in 1960—providing reclaimed water to farmers and ranchers. As cities grew, centralized wastewater treatment was more widely used and improved water quality, allowing for the first small urban water reuse system for irrigation of Golden Gate Park in San Francisco in 1912 (WRA 2012).

Industrial reuse of water reclaimed from treated municipal wastewater was documented in the 1940s, with the city of Big Spring, Texas, supplying the Cosden Oil and Chemical refinery in 1944. The cities of Odessa and Amarillo followed in the 1950s and the 1960s; this was the beginning of reclaimed water use for power plant cooling in several Texas cities (Texas Water Development Board 2011). In the early 1970s, Bethlehem Steel in Baltimore, Md., began using 100 mgd of reclaimed water for industrial purposes (USEPA 2004). By 2010, 57 power plants in 16 states were using reclaimed water for power plant cooling (DOE–ANL 2007).

TERMINOLOGY

ANSI/AWWA G481 (2014), *Reclaimed Water Program for Operation and Management*, describes the critical requirements for effective operation and management of a reclaimed water program and defines reclaimed water as water recovered following treatment of domestic